AUTOMOBILE STARTING LIGHTING AND IGNITION

MANLY

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AUTOMOBILE
STARTING, LIGHTING AND IGNITION

A Practical Instruction and Reference Work on Construction, Operation and Care of All Makes and Types of Automobile Electrical Equipment

BY
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ILLUSTRATED

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PREFACE

Automobile Starting, Lighting and Ignition has been written to serve as a complete single-volume instruction and shop reference work on all phases of automotive electrical practice on modern motor cars. The arrangement of the subject matter is such as to allow the book's use in two ways: First, as a study guide for those entering this field; second, as a ready reference manual for those already employed in electric service stations.

Among the important features assisting the student are the series of self-examination questions following the last chapter and the reviews at the ends of all chapters, covering briefly the chief matters treated in the text.

From the standpoint of the practical worker, time-saving assistance will be found in the large number of wiring diagrams showing both internal and external connections of practically all the equipment in use, also in the indexing of all equipment under its maker's name, this including the wiring diagrams.

The instructions for making adjustments and settings are supplemented by the tables following the chapters covering different makes of equipment. In all cases, especial emphasis has been given to methods and tests for locating and remedying all forms of trouble.

Part II on Starting and Lighting and Part III on Ignition are independent of each other, and either may be used in connection with Part I on Automotive Electricity to give a complete treatment of either division of the work.

The Author.

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AUTOMOBILE STARTING LIGHTING AND IGNITION

PART I
AUTOMOTIVE ELECTRICITY

AUTOMOTIVE ELECTRICITY

CHAPTER I

THE ACTION OF ELECTRICITY

In a modern automobile electricity cranks the engine to start it, then fires the gasoline as the engine runs, and finally lights the road for night-time driving. As to the exact nature of electricity, the cause of these as well as all other electrical actions, many different theories have been advanced. And yet none of them, so far, have been proven correct.

It is fortunate that in spite of this lack of positive knowledge, the action of electricity in automotive work may be easily understood by thinking of is as something that can move from place to place in much the same way that water flows through pipes and into and out of tanks.

In comparing the electricity in an electrical system to the water in a water system of pipes, pumps, valves and tanks; it may be said that the electricity, like the water, is always there to begin with.

Sometimes water may come through a pipe at a rate of hundreds of gallons a minute, then again at only a gallon or two a minute. But it is the same water, the only change being in the rate of flow. Just so with electricity; it may come through a wire

with volume enough to crank an engine, or with only enough volume to light a tail lamp. It is still the same electricity, with only a different rate of flow.

The same way with pressure. The water may be driven along at a pressure of one hundred pounds to the square inch or at only a few ounces of pressure. Electricity may have a great deal of electrical pressure back of it, or only a very little, but it is only the pressure that changes.

Like water, electricity is sometimes in motion, sometimes at rest. When it is in motion through wires or other conductors it is called the electric current. When it is in motion through the air or in the space around a conductor or a magnet, it is called lines of force or magnetism. When electricity is standing still it is called static electricity or an electric charge.

All through this work, the comparison of electrical actions to similar actions in water will be of assistance in making matters clear. This comparison is, however, used only for purposes of explanation, and it should always be borne in mind that the exact nature of electricity is really unproven.

Sources of Electricity.—In automotive work electric current is produced in either of two ways. One method uses mechanical power from the gasoline engine to run an electric generator or dynamo and the generator produces electric current. The other method uses chemicals and liquids in an electric battery and the changes that take place between the chemicals produce an electric current.

Lines of force are also produced in two ways. First; with an electric current flowing through a wire, lines of force are found in the space surrounding the wire.

Second; with any magnet, lines of force are found both in the space around the magnet and in the body of the magnet itself.

An electric charge may be had by leading the electric current into pieces of metal from which it cannot escape. The pieces of metal will hold this charge for some time and then, if re-connected to the wires through which the charge entered or if connected to other wires, the charge will flow out again as an electric current.

The water analogy makes it easy to understand the forms of electricity. Electric current is like water flowing through a pipe; lines of force are like waves on the surface of a body of water; and the electric charge is like water standing still in a tank.

CURRENT MEASUREMENT

Electricity cannot be measured according to the usual standards of weight or dimensions. It can only be measured by its effects that are produced in various ways. The two values of electricity that are generally used and mentioned in this work are pressure, expressed in volts, and rate of flow, expressed in amperes.

Electricity passes through conductors, such as wires and all other metallic things, because of the pressure, or voltage, and the flow sent through the conductor by this pressure is measured as amperage. The actual flow depends on the pressure being exerted and the resistance of the wire or other conductor to the passage of the current. If the voltage remains at a constant point, the flow sent through the conductor will be in proportion to the resistance; more flow passing as the resistance becomes less, and less flow

passing as the resistance increases. Should the resistance remain the same, an increase of voltage will cause an increased flow, while a decrease in voltage will allow the flow to become less.

The resistance of a conductor depends on its size or cross section, the resistance becoming less as the size increases. Resistance also depends on the length of the conductor through which the electricity must pass, the resistance increasing in direct proportion to increase in length. Other things affecting the resistance are the material of the conductor, some

Electricity	Unit of	Water
Volt	Pressure	Pounds to Square Inch
Ampere	Flow	Gallons per Minute
Watt	Power	Horsepower

Figure 1.—Electrical and Hydraulic Units Compared.

metals being much better conductors than others, and also the temperature, high temperatures generally causing the resistance to increase.

It should be clearly understood that voltage measures only the pressure and does not indicate any particular quantity or volume of electricity. Voltage corresponds to pounds to the square inch in hydraulic work and similarly indicates only the pressure that is available when a flow takes place.

On the other hand, amperage measures only the rate at which the current passes a given point, and unless the amount of time during which this flow continues is known, the amperage does not indicate the quantity of current that has passed. Amperage

may be compared to the measurement of water flow in gallons per minute, when, unless the number of minutes is known, the quantity of water cannot be calculated. It is necessary that both time and rate enter into the computation of quantity.

The relation of the actions in a water system to the actions in the electrical system may be understood by reference to Figures 1 and 2. Figure 1 gives the electrical units in the first column, the name of the quality measured in the second column and the corresponding hydraulic units in the last column.

In Figure 2 the water system at the top includes the pump, the tank and the water motor; while the electrical system at the bottom includes corresponding parts in the dynamo, the battery and the electric motor. The water pump imparts energy to the water and forces it to a higher level in the tank. With the water at this higher level it is capable of doing work when it passes back to a lower level through the water motor. Similarly, the dynamo imparts energy to the electricity and sends it into the battery. Current from the battery is then able to do useful work when allowed to flow through the electric motor. Electricity is not produced by the battery any more than water is produced by the tank. In either case the energy imparted to the medium of work (electricity or water) simply changes conditions; in the case of water, changing its position; in the case of electricity, changing the condition of the battery plates. A return to the former state by the water or by the battery plates allows the medium to give up its energy and in doing so to perform the desired work.

The flow through any circuit when measured in amperes depends on the resistance in the circuit just as the flow of water through pipes depends on the resistance (size and condition) of the pipes. The resistance is measured in a unit called the ohm and one ohm resistance will allow one volt pressure to force just one ampere flow through a circuit.

The resistance of a conductor depends on the material of which it is made, on its length, on its size or cross-sectional area, and to some degree on temperature, high temperatures increasing resistance.

The relative resistance of various materials is shown by the following table in which copper is taken as the standard with a value of 100.

Silver	92	Platinum	570
Copper	100	Iron	612
Aluminum	183	Nickel	784
Zinc	353	Lead	1,208

The resistance of a conductor varies directly with its length, that is, a conductor 200 feet long has twice the resistance of another similar one 100 feet long, and one similar in all other ways but 50 feet long has half the resistance of the 100 foot length.

The resistance of a conductor varies inversely with its cross-sectional area or its size around. That is to say, a conductor two square inches in area has half the resistance of a similar conductor having one square inch area, and one having one-half square inch area would have twice the resistance of the one square inch size.

The relation of the measurements of pressure, flow and resistance may be summarized as follows:

A volt is the pressure required to force one ampere flow against a resistance of one ohm.

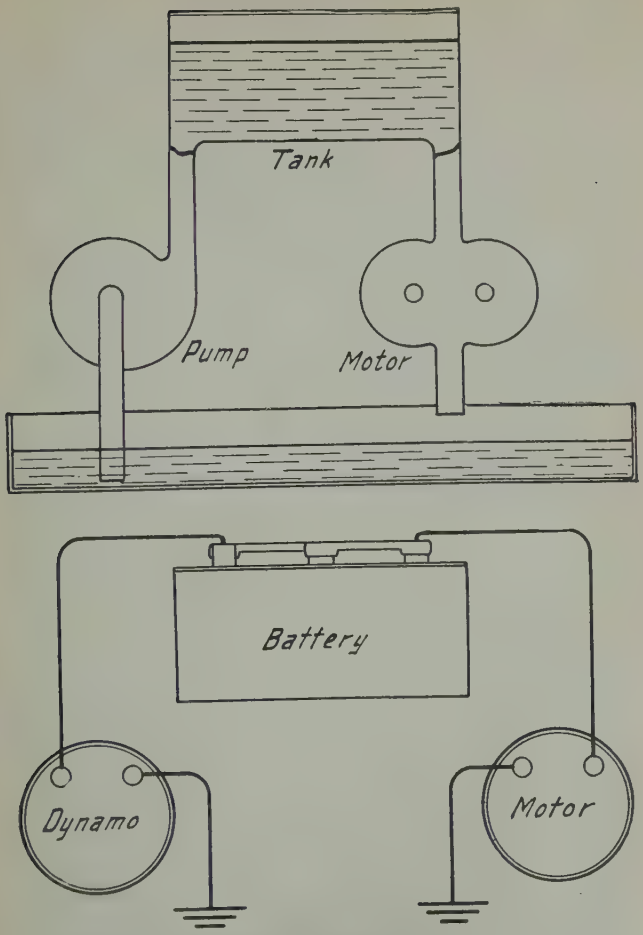


Figure 2.—Similarity Between Water System and Electrical System.

An ampere is the flow caused by an electrical pressure of one volt acting against a resistance of one ohm.

An ohm is the resistance that will allow a flow of one ampere to pass when the pressure is one volt.

The number of volts may be found by multiplying the number of amperes of current by the number of ohms resistance.

The number of amperes may be found by dividing the number of volts pressure by the number of ohms resistance.

The number of ohms may be found by dividing the number of volts by the number of amperes of current.

It will thus be seen that, knowing any two of the three values: volts, amperes, and ohms; the third one may easily be found.

Electric Power.—The useful work that electricity will perform depends on the pressure or voltage and on the volume or amperage. A current of ten amperes at a pressure of one volt will do exactly the same amount of work that will be done by a current of one ampere at a pressure of ten volts. Any other number of volts and number of amperes which, as two amperes and five volts, multiplied together will give ten, will likewise do the same amount of work.

The power of an electric current is measured in watts, one watt being the power furnished by a flow of one ampere at a pressure of one volt. The number of amperes multiplied by the number of volts will give the number of watts in any case. Thus, a lamp through which a current of two amperes is flowing at a pressure of six volts, is receiving twelve watts in electrical power. An electric starting motor through which one hundred amperes is flowing at

twelve volts is receiving twelve hundred watts in electrical power. Seven hundred and forty-six watts in electrical power is the equivalent of one mechanical horse power.

Quantity of Electricity.—It has already been stated that the quantity of electricity is not measured in amperes, since amperes measure only the rate of flow. In automotive electrical work the quantity of electricity is generally measured in ampere-hours. One ampere-hour is the quantity of electricity that will pass through a circuit on one hour if the flow is one ampere. Two ampere-hours will pass in one hour if the flow is two amperes, or will pass in two hours if the flow is one ampere. The number of ampere-hours is found by multiplying the number of amperes flow by the number of hours and fractions of an hour that the flow continues. In the same way, the quantity of water, measured in gallons may be found by multiplying the number of gallons per hour passing through a pipe by the number of hours and fractions of an hour that the flow of water continues.

Speed of Electricity.—Although the amperage in a circuit is often spoken of as the rate of flow, the meaning of the word "rate" in this case is not the same as its meaning when a car is said to be traveling at a rate of thirty miles an hour. The rate of flow in electrical work does not mean the rate of speed and for that reason it is usually better to use the words flow or volume, rather than rate, to denote amperage.

As a matter of interest, although of no practical importance in this work, when electricity enters a circuit it travels at a rate of speed of 186,000 miles in a second; the same speed at which light travels.

OHM'S LAW

The relation between volts, amperes, and ohms, which has already been mentioned and from which any one of the values can be found when the other two are known, is called Ohm's law. The rules based on this law are among the most useful in this field and it is best to become familiar with their application to practical problems.

In writing Ohm's law, use is made of symbols or letters which stand for volts, amperes and ohms. For volts the letter E is used, standing for *Electromotive Force;* for amperes the letter I is used, standing for *Intensity* of current; and for ohms the letter R is used, standing for *Resistance.*

The number of ohms resistance is equal to the number of volts divided by the number of amperes. Written in the form of an equation this would be:

$$Ohms = \frac{Volts}{Amperes}$$

Substituting the letters or symbols, the equation is:

$$R = \frac{E}{I}$$

The number of volts pressure is equal to the number of amperes times the number of ohms, and as an equation this would be:

$$Volts = Amperes \times Ohms$$

Then, substituting the letters, the equation is:

$$E = I \times R$$

The number of amperes is equal to the number of

volts divided by the number of ohms, and as an equation this is:

$$Amperes = \frac{Volts}{Ohms}$$

And substituting the letters:

$$I = \frac{E}{R}$$

If one of these equations is true, then the others must also be true, as may be easily seen by taking certain values for the letters; for example, 3 amperes, 6 volts, and 2 ohms as the values in a certain circuit. Then, taking the first equation and substituting these numerical values, we have:

$$R = \frac{E}{I} \quad \text{or} \quad 2\ (ohms) = \frac{6\ (volts)}{3\ (amperes)}$$

It is seen that 2 is equal to 6 divided by 3, as the equation shows.

Then, taking the second equation and substituting the numbers:

$$E = I \times R \quad \text{or} \quad 6 = 3 \times 2$$

And, taking the third equation with the numerical values:

$$I = \frac{E}{R} \quad \text{or} \quad 3 = \frac{6}{2}$$

Taking the circuit shown in Figure 3, consisting of a battery, an ignition coil, an ignition breaker, and their connecting wires, an ammeter could be inserted as shown to measure the current flow. But without knowing one of the other values, volts or ohms, nothing more could be learned.

If, as in Figure 4, a voltmeter is connected to measure the voltage through the coil with the am-

meter still in place, it may be found, for example, that the current is 3 amperes and the pressure is 6 volts. Then, substituting these values in the proper equation, it will be shown that:

$$R = \frac{E}{I} \text{ or } Ohms = \frac{6\ (volts)}{3\ (amperes)} = 2\ ohms\ resistance$$

Figure 3.—Ammeter Measuring Current Flow.

In this way it is known that the resistance of the coil is 2 ohms.

To learn the resistance of the coil, the breaker, and their connecting wire, the voltmeter would be placed

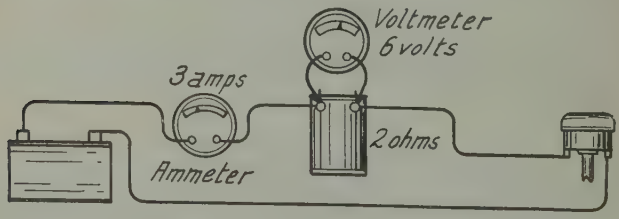


Figure 4.—Voltmeter Measuring Coil Voltage.

across these parts as in Figure 5. Assuming the voltage reading to be 9 with the amperage remaining at 3 as before, the resistance of these parts would be found by dividing this voltage (9) by the amperage

(3), which would show the resistance of the three parts together to be 3 ohms.

In the circuit shown in Figure 6, the voltage of the battery is assumed to be 6, while the ammeter shows a current flow of 2 amperes. Then, substituting these

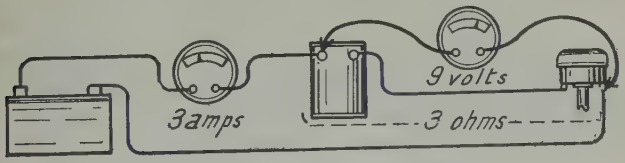


Figure 5.—Resistance Test With Voltmeter.

values in the equation, the number of volts (6) would be divided by the number of amperes (2), giving the resistance of the whole circuit from battery terminal to battery terminal as 3 ohms.

In Figure 7 the ignition coil, the breaker, and their connecting wire have been transferred to a cir-

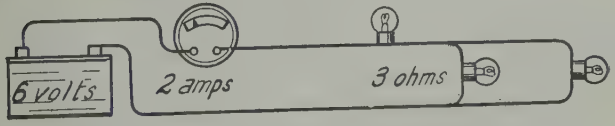


Figure 6.—Resistance Calculation With Ammeter.

cuit having a generator as the source of current. It was previously determined that the total resistance of these three parts is 3 ohms, and an ammeter may be used to find that the current flow is 1½ amperes as shown. Substituting these known values in the proper equation gives:

$$E = I \times R$$

or $Volts = 1\frac{1}{2}\ (amperes) \times 3\ (ohms) = 4\frac{1}{2}$

Thus, without using a voltmeter, it is known that the pressure across the ignition coil and breaker is $4\frac{1}{2}$ volts.

Figure 7.—Voltage Calculation From Amperage.

In Figure 8 the pressure is measured with a voltmeter and the resistance of the coil, the wire, and the breaker is known to be 3 ohms from the previous test.

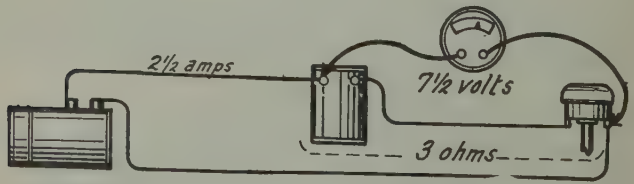


Figure 8.—Amperage Calculation With Voltmeter.

To find the amperage, the known values are substituted in the proper equation, giving:

$$I = \frac{E}{R} \quad \text{or} \quad Amperes = \frac{7\frac{1}{2}\ (volts)}{3\ (ohms)} = 2\frac{1}{2}\ amperes$$

Thus, without using an ammeter, it is known that the current flow is $2\frac{1}{2}$ amperes.

Internal and External Circuits.—Every circuit may be considered as being made up of two parts, one part being called the external circuit and the other called the internal circuit. The external circuit includes all the conductors and all the units outside the source of current, the dynamo or battery, as the case may be. Through all of this external circuit the current flows from the positive terminal of the source toward the negative terminal as shown in Figure 9.

The part of the circuit inside of the battery, dynamo, or other source is called the internal circuit. In this part of the circuit the current flows from the negative terminal to the positive terminal.

POLARITY

The theory which assumes that electric current flows through conductors also assumes that this flow has a certain direction of motion. Any flow of current must start from its source and after doing the desired work must again return to the source, keeping up this flow until the current is interrupted.

Every source of current therefore has two parts, one from which the current flows and the other to which it returns. The side from which the current starts from the source is called the positive, and the side to which it returns is called the negative.

Flow of current is caused by electrical pressure measured in volts. In order that there may be a flow of current there must, therefore, be a difference of pressure between two points, and this difference of pressure will cause a flow of current from the point of higher pressure to other points of lower pressure. The points of high pressure are said to be positive and those of lower pressure are said to be negative.

The earth itself is considered as having no electrical pressure or zero pressure. Any point having greater pressure than that of the earth is called positive, while all points having pressure below that of the earth are negative.

Current flow, as shown in Figure 9, is always away from a positive point and toward a negative point while outside of the source. Points which are positive are marked with a plus sign (+) or with the letters "POS" or "P," and points which are negative are marked with a negative sign (—) or with the letters "NEG" or "N".

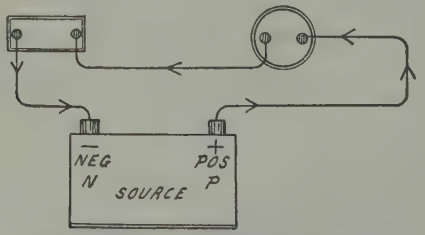


Figure 9.—Path of Current in the Electric Circuit.

ELECTRICAL CONNECTIONS

The electric current from any source leaves from the positive side and, as has been explained, returns to the negative. Between the positive and negative sides the current may follow a path through one or more conductors and electrical devices of various kinds.

Should all of the current from the source pass first through one part of the path and, without any of the current being diverted, pass in succession through all

of the devices and other conductors before returning to the negative side of the source, all of the parts outside of the source are said to be connected with each other and with the electrical source in a series connection, this arrangement being shown at the top of Figure 10.

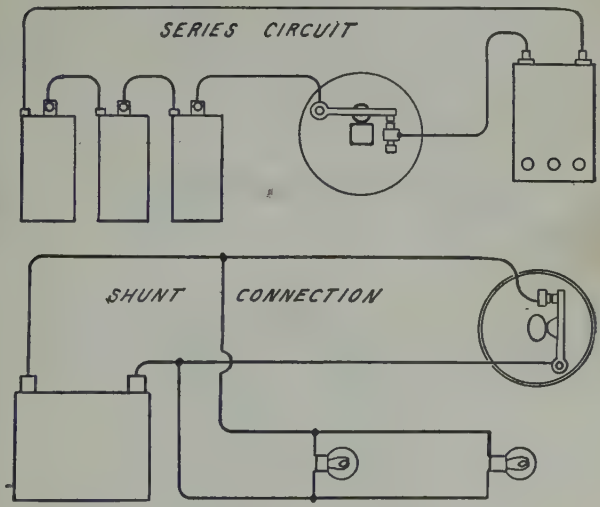


Figure 10.—Series and Shunt Circuits.

A series connection may then be defined as a connection made between several sources of current or between several current consuming devices in such a way that all of the current that passes through any one unit or conductor will also have to pass through every other unit and conductor in the circuit. In the case of parts having definite polarity the positive side of one will be connected with the negative of the

next and the positive of this second part with the negative of the third, and so on.

If, after leaving the source, the current divides and part of it takes one path while the remainder takes another path or several other paths before returning to the source, the parts or various paths carrying the current are said to be in shunt with each other and the connection is called a shunt circuit. Such a connection is shown at the bottom of Figure 10. Some forms of shunt connections are called multiple or parallel connections.

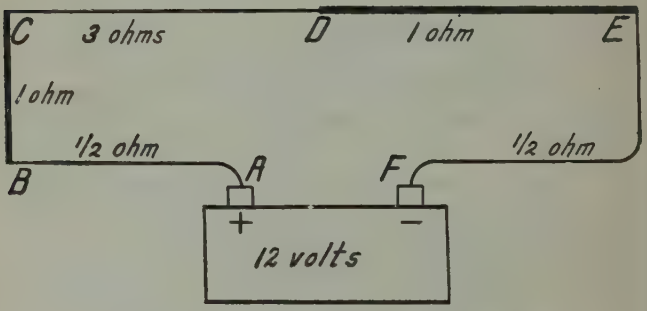


Figure 11.—Resistances in a Series Circuit.

Series Circuit.—Figure 11 illustrates a series circuit made up of five different conductors attached between the terminals of a 12-volt battery and with the assumed resistance of each part marked for reference.

The resistance of a series circuit is equal to the sum of the resistances of the parts included in the circuit. Therefore, the resistance of the circuit in Figure 11 is found as follows:

A to B	½ ohm
B to C	.1 ohm
C to D	3 ohms
D to E	.1 ohm
E to F	½ ohm
Total, A to F	6 ohms

Knowing the resistance of a series circuit and the voltage acting on the circuit (in this case 12 volts) the amperage can be found by the rule that the amperage is equal to the voltage divided by the ohms. In Figure 11 then, dividing 12 (volts) by 6 (ohms) gives the flow as 2 amperes. The current flow is the same through all parts of a series circuit regardless of the resistance of the part being considered. Thus, the current through the circuit from *C* to *D* against 3 ohms resistance is 2 amperes and the current through the circuit from *A* to *B* against ½ ohm resistance is likewise 2 amperes.

In the example being considered it is known that there is a pressure of 12 volts between the ends of the circuit *A* and *F*, and it is evident that it requires 12 volts to send 2 amperes through this circuit. Yet there will not be 12 volts pressure between *C* and *D*, for example, because it is known that it does not require 12 volts to send 2 amperes against 3 ohms resistance. The rule has been given that voltage is equal to the number of amperes times the number of ohms and, applying this rule between *C* and *D*, 2 (amperes) times 3 (ohms) we find that 6 volts pressure is required. This pressure of 6 volts is used between *C* and *D* and their *potential difference* is said to be 6 volts. Similarly the potential difference between any other points may be found; as from *B* to *C*, 1 ohm times 2 amperes indicates 2 volts drop from *B* to *C*.

Referring to Figure 12, let the left hand vertical line represent the initial 12 volts acting on the circuit. The bottom horizontal line represents the parts of the circuit, *A-B*, *B-C*, etc., each part being of a length proportional to its known resistance. Between *A* and *F* the drop is equal to twelve volts so the upper slanting line can represent this total voltage drop. The potential difference between any two points in the circuit is seen to be proportional to the resistance between those points and it can also be readily seen

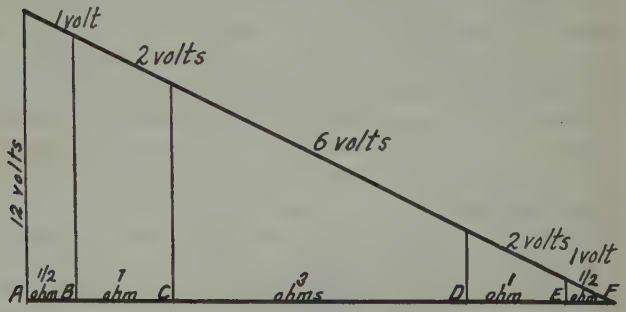


Figure 12.—Drop of Potential in Series Circuit.

that the sum of all the potential differences is equal to the voltage acting on the circuit. The conclusions drawn from Figure 12 can easily be verified by applying the rules for determining voltage, amperage and resistance in ohms.

Shunt Circuit.—For purposes of explanation, the shunt circuit will be treated as if the conductors forming the shunts were each attached between the common source of pressure and current. It will often be found, however, that a shunt circuit will form a part of a series circuit as in Figure 13. In the illus-

tration, that portion of the circuit between A and B would be treated as a series circuit and so would the portion from C to D. In this way it would be possible to determine the amperage flowing through the shunts *M* and *N* from *B* to *C* and to find the potential difference between *B* and *C* which would be the voltage acting on the shunt circuit.

If the source of Figure 13 is considered as having 12 volts pressure, if the lines *A-B* and *C-D* have 2 ohms resistance each and if the shunt circuit *B-C* has

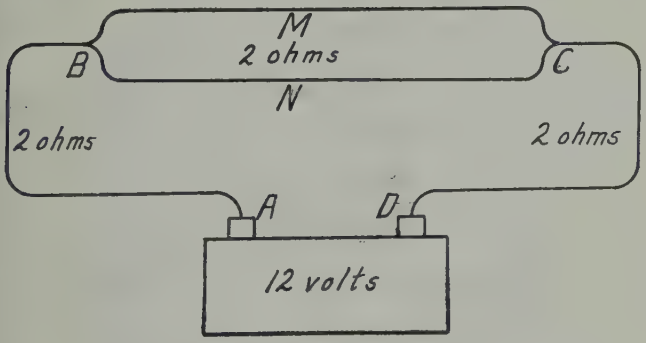


Figure 13.—Resistances in a Shunt Circuit.

2 ohms, then 2 amperes will flow in each part and 2 amperes will flow from *B* to *C*, dividing between *M* and *N*. Knowing the amperage in *B-C* and its resistance, each being 2, then multiplying 2 by 2 gives the potential difference as 4 volts between *B* and *C*. This 4 volts pressure acts on *M* and also on *N*.

It is often desired to find the combined resistance of all the parts forming a shunt circuit, or to find the current flowing in each branch when the resistances of the branches are known.

If all of the branches of a shunt circuit have the same resistance, as with the four parts of the circuit *A-B* in Figure 14, the resistance of the entire circuit is found by dividing the resistance of one branch by the number of branches. Thus, in *A-B* of Figure 14, dividing 8 (resistance of one branch) by 4 (number of branches) gives the combined resistance as 2 ohms. The resistance of any shunt circuit is always less than the resistance of any of its branches, because providing the current with several paths makes it easier for

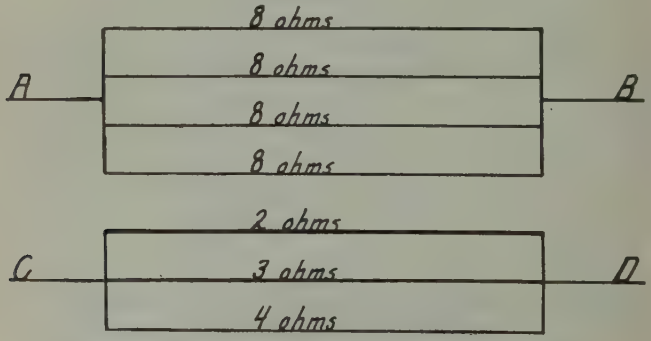


Figure 14.—Calculating Shunt Circuit Resistance.

the electricity to flow than would be the case with any one path of the several.

If the resistances of the several parts of a shunt circuit differ from one another, their combined resistance is found as follows: All of the resistances are multiplied together and the product forms the upper part or numerator of a fraction which will show the total resistance. Thus, in *C-D* of Figure 14, multiply $2\times3\times4=24$ which will be the numerator. Then multiply each resistance by each one of all the

other resistances and add together all the numbers thus found. In *C-D* of Figure 14, this would be done as follows: (2×3) plus (2×4) plus $(3\times4)=6+8+12=26$ which will be the lower part or denominator of the fraction to be found. It will be seen that in the latter operation each resistance was multiplied by each of the other resistances. The fraction indicating the resistance of the shunt circuit *C-D* will then be 24/26 or 12/13ths of an ohm. The same method can be applied to any number of shunts.

If the potential difference or voltage between the ends of any one shunt is known and if the resistance of the shunt is known; the flow through that branch may be found by applying the rule: amperage is equal to the voltage divided by the resistance. Thus, in *C-D* of Figure 14, if the potential difference is assumed to be 12 volts, then the flow through the 2-ohm branch will be 12 divided by 2, or 6 amperes; the flow in the 3-ohm branch will be 12 divided by 3, or 4 amperes; and the flow in the 4-ohm branch will be 12 divided by 4, or 3 amperes. The total flow will then be equal to the sum of the flows in the branches, or $6+4+3=13$ amperes.

This conclusion can be proven correct because the total resistance of the circuit *C-D* was previously found to be 12/13ths of an ohm and applying the rule, amperage is equal to voltage divided by resistance, and dividing 12 (the voltage) by 12/13 (the resistance) the amperage is found to be 13.

KINDS OF CURRENT

The work so far has considered only electric currents which always flow in the same direction and whose voltage and amperage remain at constant

values as long as the circuit resistance and the pressure from the source remain unchanged. Such currents are called direct currents and are the only kind used in automotive work for charging, for generating, for engine starting, and for lighting.

In other branches of electrical work another form of current, called alternating current, is used a great deal. The polarity or direction of flow and the voltage of alternating current reverse at rapid intervals as shown in the center of Figure 15, which shows the voltage curves of three forms of current. The top line represents the voltage of direct current, which

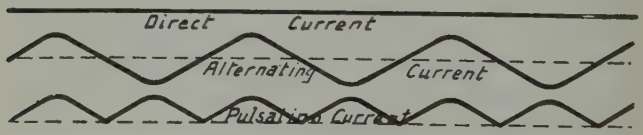


Figure 15.—Direct, Alternating and Pulsating Currents.

remains constant. The middle line represents alternating current, which alternately rises from zero to its full voltage in one direction of flow, then goes back past zero and to an equally high voltage in the other direction. Except in some forms of ignition systems, alternating current is not used in automotive work until it is changed into direct current.

The lower line in Figure 15 represents a pulsating direct current in which the voltage rises from zero to its maximum, then drops back to zero and rises again. The polarity, or direction of flow, always remains the same and there is no reversal as with alternating current. This pulsating current is used in ignition work and sometimes for battery charging.

CHAPTER II

MAGNETISM AND INDUCTION

Magnetism and induction are the means used for the production of electric current in automotive work, and they are the means by which the electric current from the battery or generator may again be used for producing ignition sparks and for operating the electric starting motor. These subjects are, therefore, of great importance.

MAGNETISM

Like electricity, magnetism can be described only by telling of its action and effects, and the action most commonly thought of is that by which a magnetic piece of iron or steel attracts another piece of iron or steel to itself.

Magnetism is assumed to flow in magnetic lines of force and these lines of force travel in magnetic circuits through the magnet and through the space immediately surrounding the ends or poles of the magnet.

These lines of force pass through the metal of the magnet from one end to the other and after issuing from the magnet travel through the surrounding space to re-enter again, thus keeping up a continuous travel or magnetic circuit as shown in Figure 16. The end of the magnet from which the lines of force leave the magnet is called its positive pole, and the end at which they re-enter is called the negative pole.

A piece of iron or steel may be made a magnet through the influence of another piece that is already magnetic or by being acted upon by the electrical influence from a conductor carrying current. A magnet shows attraction for another magnet or for any piece of iron or steel near it.

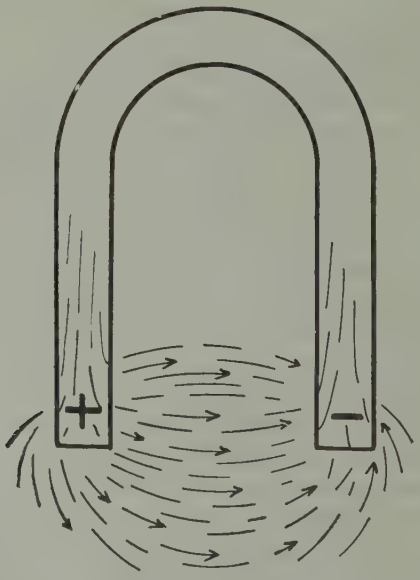


Figure 16.—The Field Around a Magnet.

The end at which the lines of force enter, the negative pole, in other words, may also be called the South pole, while the end from which the lines of force leave is called the positive or North pole. The space in which the lines of force travel outside the magnet is called the magnetic field.

While all metals are conductors of electric current, only iron and steel can become magnets. However, lines of force easily pass through all other substances, metal or otherwise, as if the substances did not exist. Magnetism can be controlled only by providing paths of iron or steel for it to travel through, there being no materials that confine magnetism as insulators confine electric current.

A hard steel magnet retains magnetism until heated, jarred, etc., and is called a permanent magnet. Soft iron will not retain magnetism and remains magnetic only while in the field of another magnet or of a current-carrying conductor. Soft iron in contact with a magnet becomes magnetic itself.

Magnets brought near each other with like poles together show repulsion for each other; with unlike poles together, they attract each other. Two positives or two negatives repel, while a positive and a negative attract.

Magnets placed together with like poles together form a compound magnet stronger than a one-piece magnet of the same weight as all the parts together. Magnets placed together with unlike poles (positive and negative) next one another, neutralize each other's strength and there is no useful outside magnetic field.

The field around the poles of a U-shaped magnet is shown in Figure 16, with the lines of force passing from the positive to the negative pole. Several forms of magnets are shown in Figure 17. The principles governing the magnetic action are not changed by the shape of the magnet, the same rules of field lines, attraction, repulsion, etc., applying regardless of the form adopted.

ELECTROMAGNETISM

A conductor through which is flowing an electric current is surrounded by circular lines of force which whirl around the conductor as a center. These lines of force always travel around the conductor in one direction relative to the direction of current flow through the conductor and as shown in Figure 18 at the left. If the current flow is reversed through the conductor, the direction of the lines of force is also reversed.

Should the conductor be made into a coil as shown at the right in Figure 18, the lines of force will not

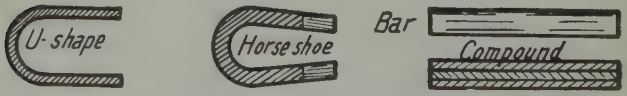


Figure 17.—Forms of Magnets.

make complete circles around the turns of the conductor, but will pass completely through the coil, which is now a *solenoid*, and will then return in the other direction around the outside of the coil. If a piece of iron be placed within the solenoid the lines of force that were traveling inside the coil will travel through the iron in that same direction as shown in Figure 19, making the iron a magnet whose polarity corresponds to the direction in which the current flows through the conductor. This combination of an iron core and a coil of conductor is called an electromagnet. The strength of the electromagnet depends on the number of amperes flowing through the coil and on the number of turns of the conductor around the iron core.

To produce a strong magnetic effect in iron or steel, the current carrying conductor is wound around the metal. The lines of force then go through the metal, called the core, and their direction through

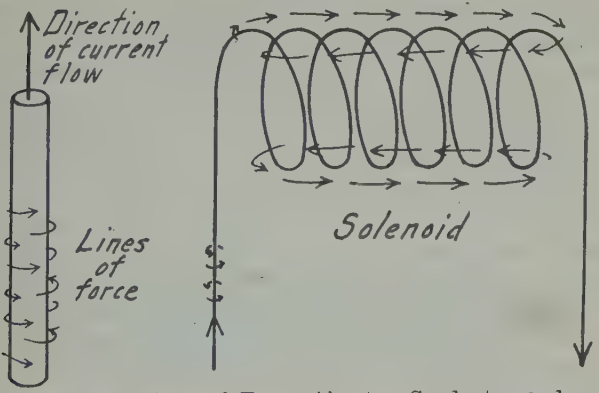


Figure 18.—Lines of Force About a Conductor and a Solenoid.

the core depends on the direction of current flow through the conductor and on the direction in which it is wound around the core.

The core of an electromagnet is made from soft

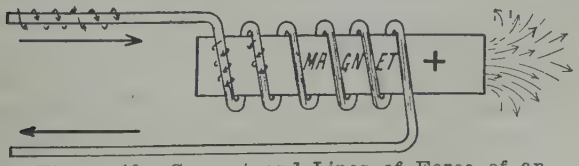


Figure 19.—Current and Lines of Force of an Electromagnet.

iron, usually in thin sheets or lengths of wire in place of in a solid piece. Such a magnet retains its magnetism only as long as current flows through its winding. A small amount of magnetism remains in

the core, no matter how soft the iron may be, and this remaining magnetism is called residual magnetism.

INDUCTION

Mutual Induction.—In Figure 20 are two coils of wire, one inside the other and both wound around an iron core. If the current flowing through one coil is increased and decreased, or if the current is alternately started and stopped, there will be changes of the number of lines of force surrounding the core. This change, whether increase or decrease of the lines of force, will affect the second coil and will induce a voltage or pressure in it. If the ends of the second coil are connected to an electric circuit, a current will be caused to flow in the circuit by this voltage.

Even if there were no core inside the coils, the same action would take place, but the effect on the second coil would not be as great because the magnetic field would be weaker without a core. Similarly, with two conductors lying alongside each other, even if not formed into a coil, there will be the same action, but still weaker. This action of inducing a voltage and a flow of current in one conductor by changes in current flow through another conductor is called mutual induction, and it is on this action that the ignition coil depends.

Self-Induction.—It will be realized that the same change in magnetism of the core or of lines of force in Figure 20 that affect the second coil will also react on and affect the first one. This action of the first coil on itself produces an induced current in the first coil, called the current of self-induction.

With a coil of many turns this voltage of self-induction, often called the inductance of the coil,

may be many times greater than the original voltage flowing through the coil. With an increase of current from the outside source, the polarity of the induced current is such as to oppose the polarity of the outside current and to hold back this current. Then, when the current from outside starts to decrease, the induced voltage is of the same polarity as that of the outside current and therefore helps the outside current and keeps it from decreasing. These two facts may be stated by saying that the induced current, or the current of self-induction, always opposes any change in the inducing current.

Figure 20.—Coils Around an Iron Core.

The voltage caused by induction is the result of a cutting through the coil by the lines of force. Any change in the number or strength of these lines causes them to move out from the magnet in increasing number or to come back into the magnet in diminishing number. As the lines move across the conductors, cutting through the conductors, the action induces the voltage that causes the induced current to flow in a circuit.

ELECTROMAGNETIC INDUCTION

It has been shown that a flow of current through a coil produces a magnetic field around and through the coil. It is also true that movement of a magnetic field through a coil, or movement of a coil in a mag-

netic field, will produce a flow of current in the coil. This current is said to be produced by electromagnetic induction and it is this principle that it utilized to cause the dynamo to generate a flow of electric current.

In Figure 21 at the left is shown a magnet with its field and a coil outside of the field. At the right the coil is shown within the field. It is evident that the

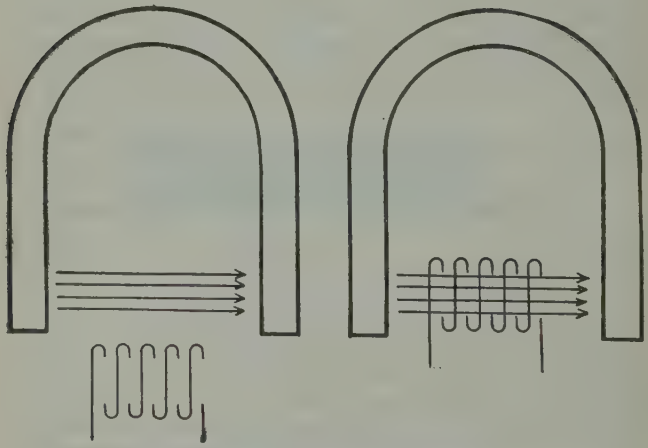


Figure 21.—Principle of Electromagnetic Induction.

condition at the right could have been brought about either by moving the magnet down over the coil or by moving the coil up into the magnet's field. In either case the result and action would be the same; namely, to change the strength of the magnetic field around the coil or to have the coil cut through the magnetic lines of force. By electromagnetic induction, this change of magnetism around the coil or the

cutting of lines of force would have caused a difference in potential between the ends of the coil and if the ends were joined there would have been a flow of current through the coil.

In place of moving either the magnet or the coil as in Figure 21, the coil could be rotated within the

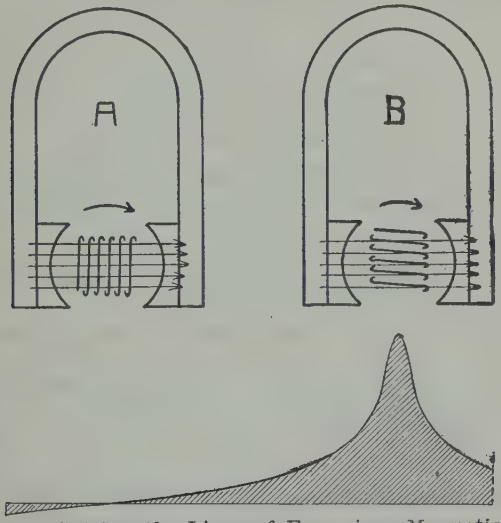


Figure 22.—Cutting the Lines of Force in a Magnetic Field. The Change of Voltage is Shown Below.

magnetic field as shown in Figure 22 and the same effect could be secured; that is, a cutting of the lines of force by the coil. Referring to Figure 22 it will be seen that with the coil in the left hand position its turns are not cutting the lines of force and there is no voltage. As the coil is turned, its conductors cut through the lines of force at a constantly increas-

ing rate until in the position at the right the lines are being cut at the greatest rate and there is a maximum voltage. This action takes place with each coil wound on the rotating part, or armature, of a dynamo or magneto, and it is in these windings that the current for battery charging or for ignition is generated by electromagnetic induction.

REVIEW OF PART I

AUTOMOTIVE ELECTRICITY

Electricity is always present in an electrical system.

The **electric current** is electricity in motion through conductors.

Lines of force or **magnetism** is electricity in motion through the space around a magnet or around a conductor carrying current.

An **electric charge** or **static electricity** is electricity standing still.

Volume of flow is measured in **amperes**, pressure is measured in **volts**, resistance is measured in **ohms**, power is measured in **watts**, and quantity is measured in **ampere-hours.**

Quantity is sometimes measured in **coulombs;** one coulomb being the quantity of electricity passing in one second with a flow of one ampere.

One **kilowatt** is equal to 1000 watts. One **watt-hour** is equal to a power of one watt used for one hour.

Conductivity is the opposite of resistance; it measures the ability of a conductor to carry electric current.

Electrical pressure (voltage) is also called **electromotive force** (E.M.F.) or **potential.**

Ohm's law is written with I for the number of amperes, E for the number of volts, and R for the number of ohms. Then we have:

$$I = \frac{E}{R} \qquad E = I \times R \qquad R = \frac{E}{I}$$

Electricity or magnetism flows **away from the positive** terminal or pole of a source and flows **toward the negative** terminal or pole.

Resistance depends on the length, cross sectional area, temperature and material of the conductor. It becomes greater with increase of length or decrease of area, and becomes less with decrease of length or increase of area. It generally increases with a rise of temperature.

In a **series circuit** all of the current in any part flows through every other part. In a **parallel or shunt circuit** the current divides between two or more paths.

The **resistance of a series circuit** is equal to the sum of the separate resistances of all the parts.

The **potential difference** between two points or the **drop of voltage** between the two points is equal to the number of amperes flowing multiplied by the resistance in ohms.

The resistance of a shunt circuit having branches of equal resistance, is equal to the resistance of one branch divided by the number of branches.

The resistance of a shunt circuit with unequal branches is equal to a fraction whose numerator is found by multiplying all the separate resistances together and whose denominator is found by multiplying each resistance by each of the others and adding these products together. With the resistances of the branches represented by a, b, c, and d, the fraction would be:

$$\frac{a \times b \times c \times d}{(a \times b)+(a \times c)+(a \times d)+(b \times c)+(b \times d)+(c \times d)}$$

Shunt circuits are sometimes said to be in **parallel or multiple** with each other.

Direct current flows in one direction with a steady voltage; **pulsating current** flows in one direction with a rising and falling voltage; and **alternating current** flows first one way then the other with a rising and falling voltage.

A **magnet keeper** is a piece of iron or steel placed across the two poles of a magnet to prevent loss of magnetism.

An **electromagnet** is formed of a soft iron core around which is a coil of conductor through which current passes.

Ampere-turns measure the **magnetic strength** of an electromagnet. The number of ampere-turns equals the number of amperes flowing, multiplied by the number of turns of the winding through which they flow.

Hysteresis is the lagging in completely demagnetizing a magnet core. It is due to the necessity for destroying the residual magnetism.

An **eddy current** is an electric current produced by lines of force cutting the conductor formed by the core of a magnet. They flow around and around in the core.

A **plunger magnet** is an electromagnet whose core, or an extension of it, is drawn into the winding when energized.

Mutual induction is the effect by which any change of current strength in one conductor or coil induces an electrical pressure in another conductor or coil.

Self-induction is the effect by which any change of current strength in a conductor induces an electrical pressure in the same conductor, this self-induction tending to oppose the change of current flow.

Electromagnetic induction is the effect by which movement of lines of force through a conductor, or movement of the conductor through lines of force, causes an electrical pressure in the conductor and may cause a flow of current.

PART II

AUTOMOBILE STARTING AND LIGHTING

AUTOMOBILE STARTING AND LIGHTING

CHAPTER I

AUTOMOBILE GENERATORS

An automobile starting and lighting system includes the generator as a source of current, the storage battery in which a part of the electrical energy is saved for future use, and the parts that consume current, either directly from the generator or from the battery. The current consuming parts include the electric starting motor, the lamps, the ignition system, and whatever electrical accessories may be on the car.

Dealing for the present only with the parts used for generating current, for starting the engine, and for lighting, they may conveniently be divided into the four divisions shown in Figure 1.

The charging system includes the generator or dynamo and the parts necessary for controlling its current, also the wiring as far as the battery.

The starting system includes the starting motor, its mechanical connection to the engine, the starting switch, and the starting wiring as far as the battery.

The lighting system includes all of the lamps, their switches, fuses, circuit breakers, and wiring. For convenience any electrical accessories such as cigar

lighters, carburetor heaters, etc., may be included with the lighting system, since their wiring is usually connected with the lighting wiring.

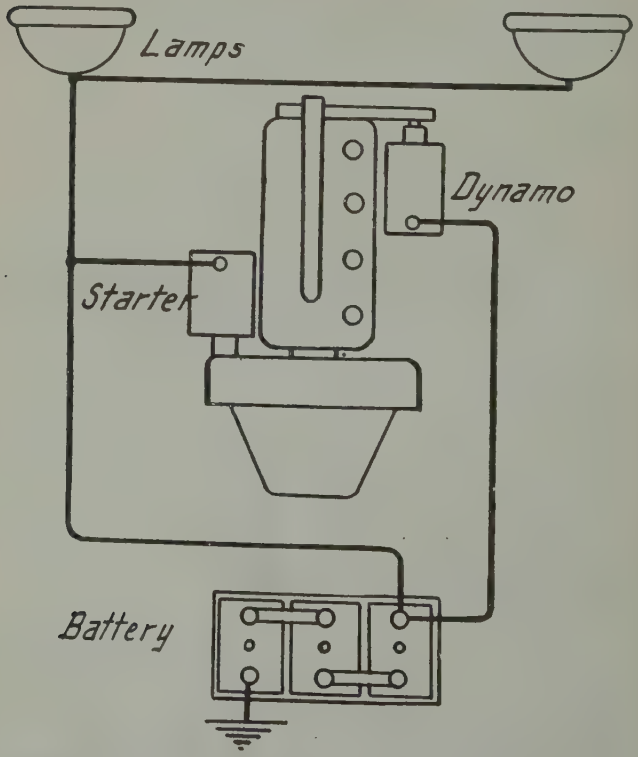


Figure 1.—Principal Parts of the Electrical System.

The fourth division consists of the battery, which, as may be seen in Figure 2, forms an essential part of each of the other divisions.

In Figure 2 it can plainly be seen that the generator and the battery form a complete circuit for charging; that the starter and battery form another complete circuit for cranking the engine; and the lights with the battery form a third complete circuit for lighting. The two wires attached directly to the battery are included in all three circuits, and it is generally true in actual wiring of a car that some of the wires are included in two or more circuits up to a certain point.

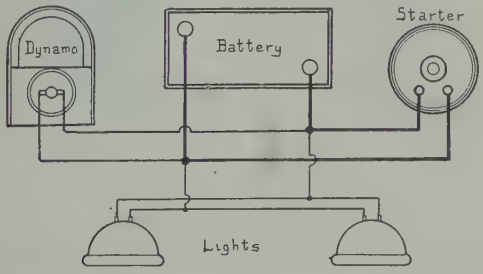


Figure 2.—Battery Relation to Dynamo Lamps and Starter.

ARMATURE AND COMMUTATOR

If a coil of wire is looped around and placed between the poles of a magnet as in Figure 3 with its ends connected to rings, the magnetic lines of force will be cut as the coil is rotated and the voltage generated will send current through the circuit as shown by the arrows. At the end of a half revolution the sides of the coil will have reversed their position, and because of the different direction of cutting the lines of force, the current will have reversed its direction of flow in the circuit. Such a machine therefore generates an alternating current.

In place of two separate rings, it is possible to use one ring in two halves as in Figures 4, 5 and 6. With the coil as in Figure 4, current may be assumed to

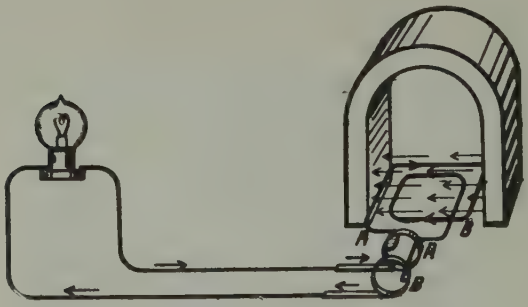


Figure 3.—The Principle of a Generator.

flow into the negative brush and the half of the ring marked *A*, then out through the half marked *B* to the positive brush. At the end of a quarter revolu-

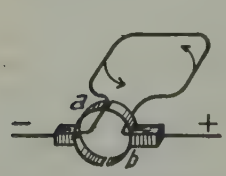


Figure 4.—Commutator Principle.

Figure 5.—Polarity Changing in the Winding.

tion, as in Figure 5, there will be no voltage, because the sides of the coil are not cutting the lines of force, this having been shown in Figure 22 of the preceding chapter. At this time the joints in the divided ring are under the brushes. When the coil has turned to the position of Figure 6, although the direction of

current flow has reversed in the coil itself just as in Figure 3, the halves of the ring have also reversed so that now the current flows into the negative brush just as before, but passes to the ring half marked *B* in its new position, then through the coil and to the half marked *A* and to the positive brush. The split

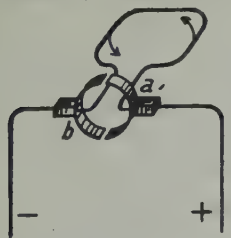


Figure 6.—Polarity Maintained Unchanged to Brushes.

Figure 7.—Connections of Two-Coil Commutator.

ring is called a commutator and its purpose is to change the alternating current to a direct current.

With a single coil, as in Figures 3 to 6, the current and voltage will rise to maximum and fall to zero twice in each full revolution of the coil, giving a

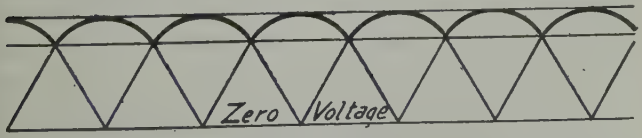


Figure 8.—Voltage Wave from Two Armature Coils.

pulsating current which is not suitable for lighting because of the flickering of the lamps that would be caused by the pulsations. By adding another coil as in Figure 7 the voltage in one coil will be rising as the voltage in the other coil is falling, and as shown by the curves in Figure 8 there will be no zero voltage points. In actual practice generators have from

twelve to twenty or more coils, so that a practically constant voltage and current flow are maintained.

It is many hundreds of times harder for magnetic lines of force to travel through air than through iron, and the magnetic field in Figures 3 to 6 would be

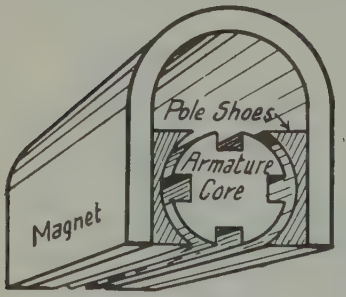


Figure 9.—Armature Position.

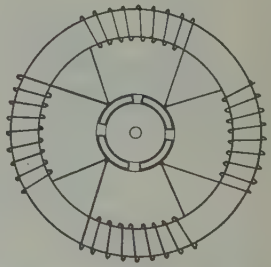


Figure 10.—Ring Armature.

weak. To make an easier path for the lines of force and thus increase the field strength or number of lines of force in a given space, the ends of the magnet are extended to form a tunnel, and in this tunnel rotates an iron "core" of soft iron as shown in Figure 9. The coils as shown in Figure 7 are placed in slots around the surface of this piece of iron.

The construction just described is called a drum armature. There is another type of armature called the ring armature, as shown in Figure 10, this being a type little used in automotive work.

ARMATURE WINDINGS

In Figure 11 three coils are shown connected to six segments of an armature. It can be seen that

coil *A* is connected to the brushes through the commutator bars attached to the ends of this coil, and a current flow may be taken from this coil. But the other two coils are connected to commutator bars that are not in contact with the brushes. These other coils are, of course, cutting through lines of force at a greater or less rate at the same time coil *A* is doing so.

To overcome this undesirable condition and connect all the coils to the brushes at all times, the ends of adjacent coils are connected together at the bars of

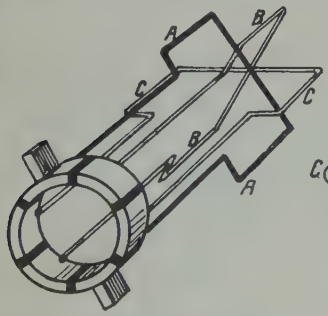


Figure 11.—Connection of Three Coils to Commutator.

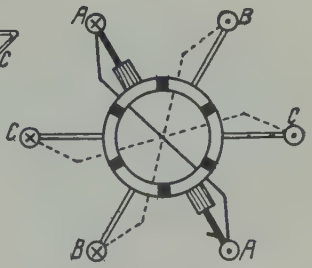


Figure 12.—Flow of Current in the Armature Coils.

the commutator so that voltage generated in one coil is added to that generated in the next one all around the armature until a brush is reached at a commutator bar. Then all of the voltage in all of the coils is available for sending current into the outside circuits.

Armature Diagrams.—To make drawings of armature coils, commutator bars, and brushes as in Figure 11 would be too laborious for practical use in shop drawings. An easier way of showing the same construction is with the front view in Figure 12. Here

the two sides of the coils are shown by the small circles, the connections to the commutator bars are shown in full lines, and the connections across the back of the commutator in dotted lines. It may be seen that coil *A* is now connected to the brushes, just as in Figure 11, while coils *B* and *C* are not connected.

In Figure 12 is shown the commonly used method of indicating the direction of current flow through a wire when looking at one end of the wire. Placing a point within a circle, as for one side of each of the coils in Figure 12, indicates that the current is com-

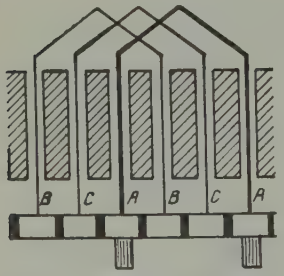


Figure 13.—Plan View of Armature Windings.

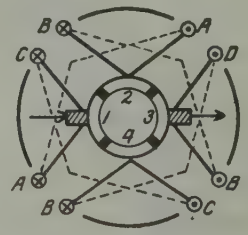


Figure 14.—Connection Between Coils at Commutator.

ing toward the observer, the point representing the point of an oncoming arrow. Placing a cross within the circle indicates that the current is flowing away from the observer, the cross representing the tail of an arrow.

The diagram in Figure 12 would be too difficult to draw for complicated armatures, and a simplified form is used. Were a sheet of paper to be wrapped around the armature in Figure 12, the conductors then marked with the letters *A*, *B* and *C*. and the paper

then unwrapped and laid flat, it would look like Figure 13, which shows a method actually used for making armature winding diagrams. In Figure 13 it will still be seen that all of the coils with their connections to the commutator bars and brushes are shown just as in Figures 11 and 12.

It has been stated that all of the coils of an armature are connected into one circuit between the brushes so that all of the generated voltage may be

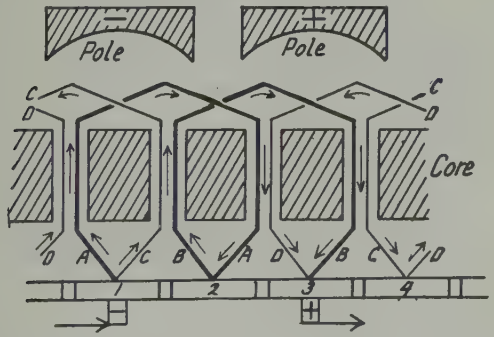


Figure 15.—The Lap Winding.

used. This is done as shown in Figures 14 and 15, both of which show the same armature. It will be seen that two coil ends are connected to each commutator bar so that the two ends are, in effect, connected together at this point. Current that has passed through the outside circuit will re-enter the generator through the negative brush and commutator bar *1*. It will then flow through coil *A* to bar *2*, into coil *B* to bar *3*, then out of the positive brush. Part of the current from the negative brush will also flow through coil *C* to bar *4*, into coil *D* to bar *3*, and out of the

positive brush together with the current that flows through coils *A* and *B*. This type is called a lap winding because it laps back toward the starting point.

Figures 16 and 17 show the circuits through the winding of the armature in Figures 14 and 15, but

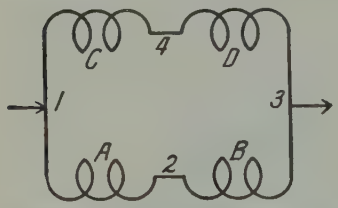


Figure 16.—Parallel Paths Through Armature.

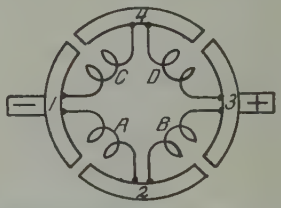


Figure 17.—Circuits Through Armature Coils.

show them in a simplified manner. It will be clearly seen in Figures 16 and 17 that there are two separate paths through the armature coils. Each coil is actually composed of many turns in each slot as

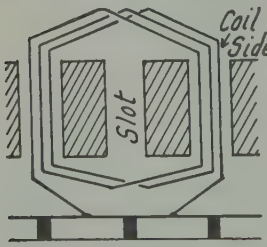
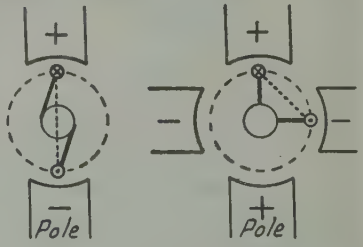


Figure 18.—Turns in a Coil.



Figures 19 and 20.—Two and Four Pole Coils.

shown in Figure 18. The part of a coil in one slot is called the coil side.

Four-Pole Generators.—With but two poles for the field magnet in a generator as in Figure 19, the opposite sides of one coil are on opposite sides of the

armature core, so that one coil may be under a positive pole while the other side is under a negative pole. In machines with four field magnet poles, the two positive poles are opposite one another and the two negative poles are likewise opposite one another as in Figure 20. Then, in order still to keep one coil side

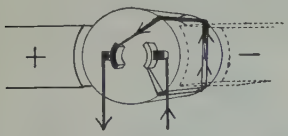


Figure 21.—Armature Coil Passing Negative Pole.

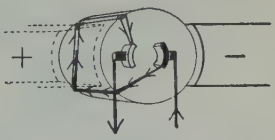


Figure 22.—Armature Coil Passing Positive Pole.

under a positive pole and the other coil side under a negative pole, the coil sides are only ninety degrees apart, as shown. The coil will then pass the pole pieces as shown in Figures 21 and 22.

In Figure 23 is shown a complete winding (without

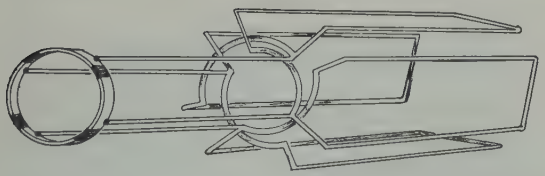


Figure 23.—Arrangement of Coils in a Four-Pole Winding.

the core) for a four-pole machine, and in Figure 24 is the front end view of this same winding with the polarity of the four magnet ends and the direction of current flow through the conductors all shown by arrows and signs. A diagram of this winding is shown in Figure 25.

Wave Windings.—When the ends of a coil do not lap back over each other, but take a wave-like form as in Figure 27, it is called a wave winding.

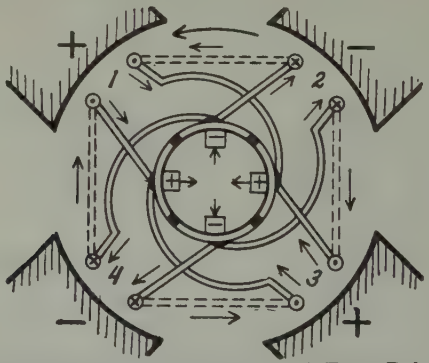


Figure 24.—Circuits Through Coils of Four-Pole Winding.

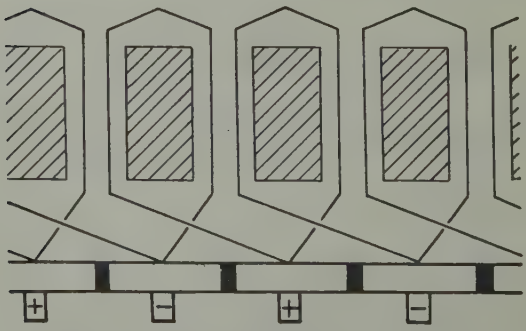


Figure 25.—Connections of a Lap Winding.

It is possible to connect a four-pole winding so that only two brushes, ninety degrees apart, are required

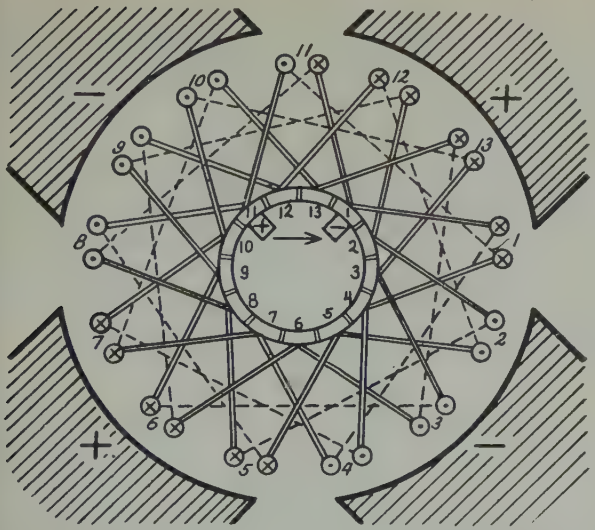


Figure 26.—Winding of Four-Pole Two Brush Machine.

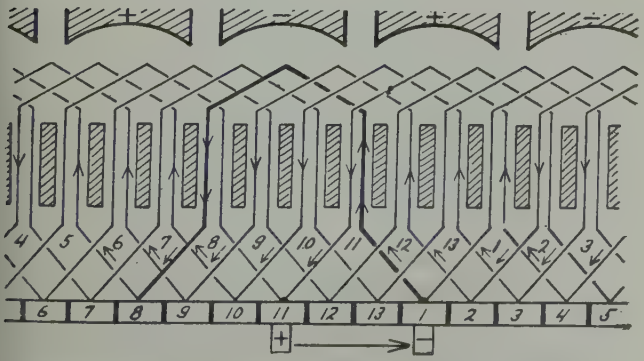


Figure 27.—Four-Pole, Two Brush Wave Winding.

in place of four. The diagram for such a connection with a wave winding is shown in Figures 26 and 27, both the end view and the plan being given. This is a practical machine with thirteen slots and thirteen commutator bars. The typical wave form may be traced through the winding and the path of the current may be traced from the negative to the positive brush.

It is unnecessary to show all of the coils in an armature winding diagram, and as a general rule only one or two coils are indicated, simply enough to show the method of winding.

BRUSH POSITION

An examination of the armature winding diagrams will show that the brushes are placed in such a position that they are connected through the commutator bars to coils that are cutting no lines of force and which are therefore generating no voltage. If high voltage were being generated in the coils connected directly to the brushes with the armature in any one position, there would be a heavy current forced through the end of the brush as it bridged across two adjacent commutator bars during the rotation of the armature. Placing the brushes on the dead spots of the armature avoids this difficulty. The dead spots would naturally be at the points midway between the field poles, but because of the effect of self-induction in the coils and the effect of what is called armature reaction in the field, the position of the brushes has to be slightly changed from that which is theoretically correct.

Armature Reaction.—Figure 28 shows the path of the field magnetism between two poles and shows the

brushes midway between the poles, where, if connected to the armature windings passing midway between the poles, the brushes would be on the dead or "neutral" point.

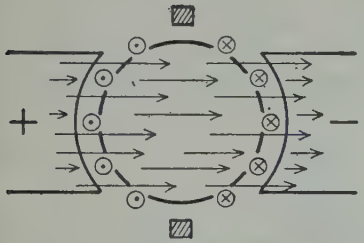


Figure 28.—Field Lines of Force.

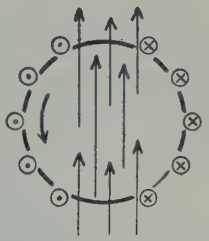


Figure 29.—Armature Lines of Force.

In Figure 29 is shown the armature taken from between the poles of Figure 28, and it will be seen that the armature current flowing around through the coil sides will make the armature core into a

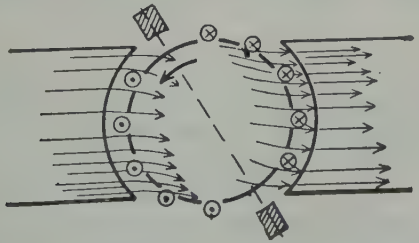


Figure 30.—Field Due to Armature Reaction.

magnet with the lines of force caused by the armature coils flowing in the direction of the arrows. With the armature placed between the field magnet poles with the direction of rotation as shown, the result of the

two magnetic fields on each other will be as in Figure 30. The lines of force will apparently be drawn around with the direction of rotation and will be crowded into the pole piece tips away from which the armature is rotating. In order to have the brushes in the true neutral position for this new shape of the magnetic field, they will have to be shifted slightly in the direction of armature rotation just as they are shown in Figure 30.

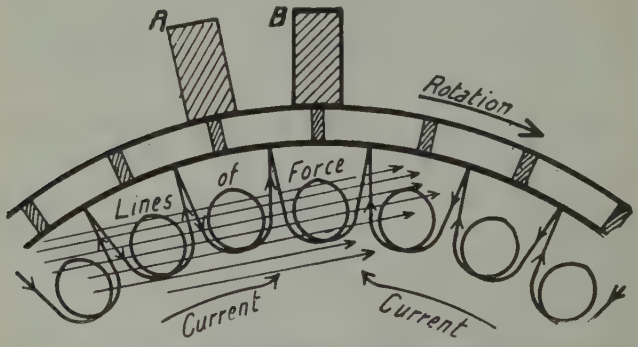


Figure 31.—Effect of Self-Induction on Brush Position.

Self-Induction in the Armature.—From the diagrams of armature windings in Figures 15, 16, 17 and 27, it will be seen that the armature currents always come to the brush from two directions. through the two parallel paths in the armature circuit. It will also be recalled that the effect of self-induction in any conductor is to oppose any change in current strength in that conductor, and, of course, with the armature coils wound on the soft iron of the core, the electromagnetic action causes self-induction in the armature winding.

Looking at Figure 31 and assuming that the brush in position *A* is on the neutral position with reference to the effects of armature reaction, the current from the two parallel paths through the armature will be coming to the brush as shown by the arrows with the direction of motion of the commutator as indicated. As the commutator segments and their attached coils pass under the brush end the current should change so that it will always be coming through both paths into the brush through the commutator segment

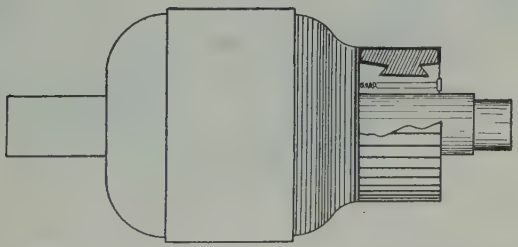


Figure 32.—Construction of a Commutator.

directly under the brush. But, because self-induction tends to prevent an instant change of current through the coils as they pass under the brush, the complete change of current direction will be delayed until the coil has passed through the neutral point, considered with reference to the field lines of force. In order to allow time for the change to take place in spite of self-induction, the brush has to be moved still farther in the direction the armature rotates until it is in the position marked *B* in Figure 31. Unless the brushes are in the proper position to allow for both armature reaction and for self-induction, there will be considerable sparking between the brush and the commutator.

A section through part of a commutator showing the shape of the bars is shown in Figure 32, while the

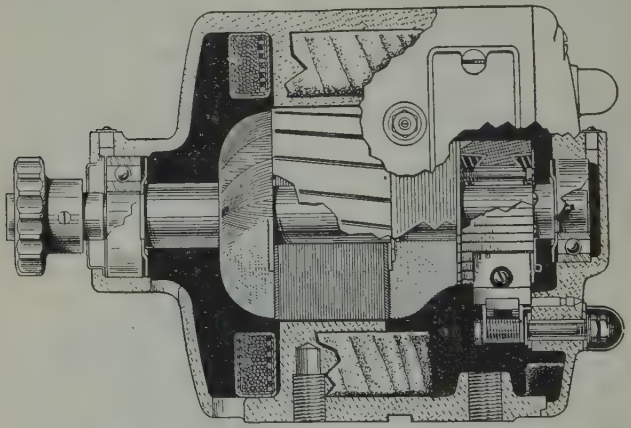


Figure 33.—Details of Generator Armature and Fields.

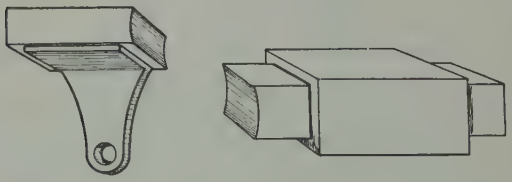


Figure 34.—Pivoted and Sliding Brush Holders.

details of a typical generator construction are shown in Figure 33. Two methods of mounting brushes on their holders are shown in Figure 34.

REVIEW OF CHAPTER I

AUTOMOBILE GENERATORS

The charging system includes the generator, regulator, cut-out and battery. The **starting system** includes the motor, starting switch and battery. The **lighting system** includes the lamps, switches, fuses or circuit breaker, and the battery.

The **generator armature** includes the iron core and the coils or windings.

The **commutator** changes the alternating current from the armature coils into direct current through the brushes by keeping all coil sides of one polarity connected to a brush of the same polarity and all opposite coil sides to the brush of opposite polarity.

All of the coils on an armature are connected together at the commutator so that all the pressure from all the coils is used.

There are **two parallel circuits** from brush to brush through the armature windings.

The ends of the coils in a **lap winding** come back toward their starting point. In a **wave winding** the coil connections run around the core in a wave-like form.

Armature reaction displaces the field lines of force so that they seem to be carried around slightly in the direction of armature rotation.

Brushes should rest on the commutator at points where there is the smallest difference of voltage between the coils attached to the adjacent bars under the brush end. The displacement of the field due to armature reaction, and the lag of current in the armature coils due to self-induction, make it necessary to move the brushes some distance around with the direction of armature rotation to bring them to this position.

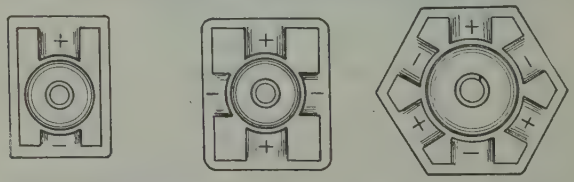
CHAPTER II

GENERATOR CONTROL—STARTING MOTORS

The output of automobile generators is controlled by controlling the strength of the field magnetism. Because these generators are of the variable speed type, driven directly from the engine, field control forms the most practical method of output control.

FIELD MAGNETS

In a field magnet having but one positive pole and one negative pole, these two poles are placed opposite



Figures 35, 36 and 37.—Two-Poles, Four-Poles and Six-Poles.

each other as in Figure 35. With more than two poles, the positives are placed opposite each other and the negatives opposite each other as in Figures 36 and 37. The paths of the lines of force through a four-pole field magnet are shown in Figure 38, and it will be seen that opposite poles are of the same polarity.

In some of the older machines, permanent magnets were used for the fields, but nowadays practically all generators have their fields formed of electromagnets. As can be seen in Figure 38, the current required to

magnetize the fields is taken to the field magnet coils from connections made to the brushes. It is not necessary that all of the poles have windings upon

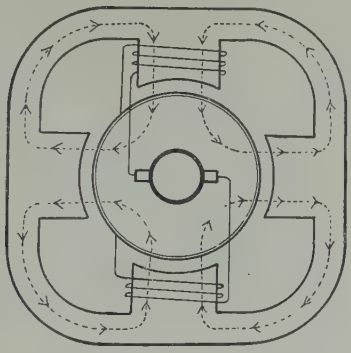


Figure 38.—Flow of Magnetism in Four-Pole Generator, Showing Consequent Poles.

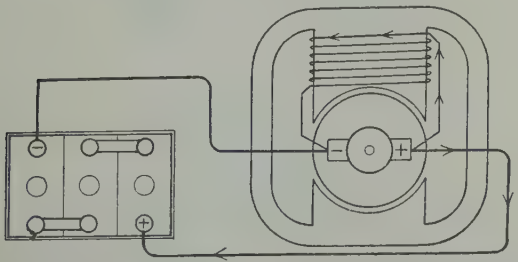


Figure 39.—Connections of a Shunt Field Winding.

them. In Figure 38 the winding is on the two positive poles, while the two negatives are unwound and are called "consequent" poles.

Field Windings.—With the armature, the outside circuit, and the field winding all in parallel or form-

ing shunts with each other, the generator is said to have a shunt wound field as shown in Figure 39. Current from the positive brush divides as shown by the arrows, part going through the field winding and part through the outside circuit. Regardless of

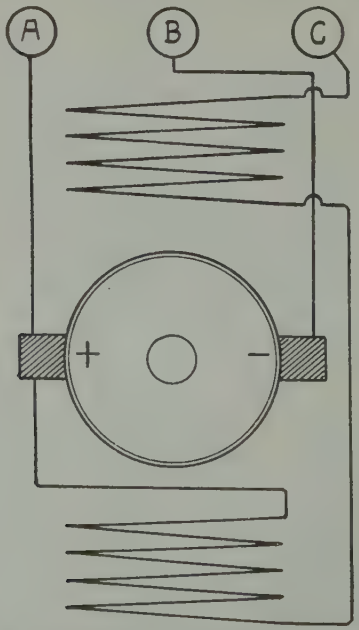


Figure 40.—A Shunt Wound Generator. (Ward Leonard)

the exact arrangement of the windings on the field poles, when the field windings are in parallel with the armature circuit, it is called a shunt field winding. Diagrams for shunt wound machines are shown in Figures 40, 41 and 42. In Figure 40 terminals *B* and *C* are connected together outside the generator, in

Figure 41 terminals *S* and "—" are thus connected, and in Figure 42 terminals $+D$ and $+F$ are connected. It is through these outside connections that the shunt field circuits are completed. All generators have shunt field windings.

With the armature, the field circuit and the outside circuit all connected in series with each other, as in

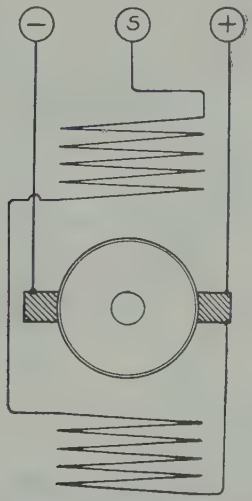


Figure 41.—A Shunt Wound Generator. (Lauraine)

Figure 43, the machine is said to have a series field winding. This winding carries all the current flowing to the outside circuits, and any changes in the outside load would cause such a great change in the field strength and the generator output that the series windings is not used alone for dynamos. It is, however, universally used for starting motors.

There are a few generators in which a shunt winding and a series winding are placed together as in Figure 44. By following the circuit from the positive brush through the shunt winding to the negative brush, then from the positive brush through the series winding to the battery, it will be seen that the

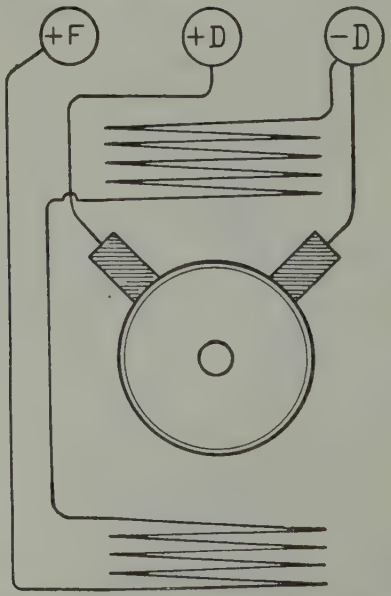


Figure 42.—Shunt Wound Generator with Ninety Degree Brushes. (Adlake)

field current flows around the magnet in the same direction through both shunt and series windings, and they therefore act together and assist each other. This is called a compound field winding.

In Figure 45 is shown another combination of shunt and series field windings. Now, tracing the

shunt field circuit from the positive brush to the negative brush, then tracing the series field winding from positive brush to battery, it will be seen that the direction of the series field current around the field magnet is opposite to the direction of the shunt

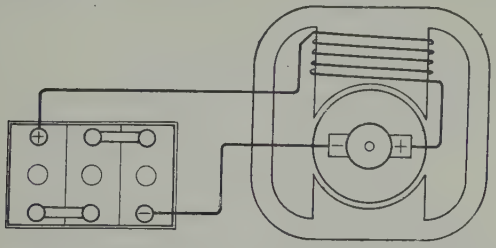


Figure 43.—Connections of a Series Field Winding.

field current. As the generator speed increases, the effect of the shunt field will be to increase the field strength and generated voltage, while the opposing flow through the series field will tend to lessen the

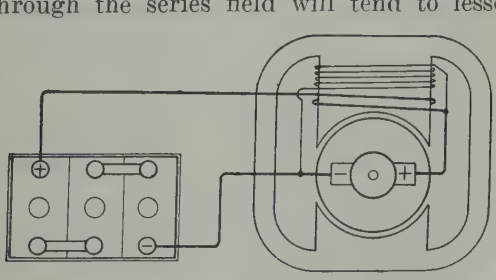


Figure 44 —Connections of a Compound Field Winding.

field strength and voltage. This is called a reversed series connection and is used as a means of limiting the generator's maximum output. This winding is sometimes called a differential field winding or a bucking coil winding.

Direction of Rotation.—Generators are designed for rotation in a certain direction and if this direction is to be changed it is necessary to change the connections of the shunt field winding to the brushes and generally to change the position of the brushes, especially in designs taking the field current through a regulating brush or third brush.

With a generator running clockwise as in Figure 46, and with the direction of field current as shown, the lower pole will be positive and the armature coils will be cutting the lines of force in a certain direction. If the rotation of the armature is reversed in direction, in order still to have the armature conductors cut the field lines of force in the same direction as before, it will be necessary also to reverse the direction of the field polarity as shown in Figure 47. Changing the connections of the shunt field will change the polarity of the field magnet and with the rotation changed the current flow through the armature conductors will remain the same as before and the brushes will still be of the same polarity as before the change of rotation.

Building Up of Generator.—It will be seen that the polarity of the brushes and of the generator terminals is determined by the polarity of the field. The dynamo starts to generate because of the weak magnetic field through the armature caused by the residual magnetism remaining in the field magnet cores. The small armature currents due to this residual magnetism flow through the field windings and rapidly increase the field strength. This increase of field strength allows the armature coils to cut a greater number of lines of force and the gen-

erator quickly "builds up" its voltage to the normal value.

GENERATOR CONTROL

The generator and the battery may be compared to the water system shown in Figure 48. Here a

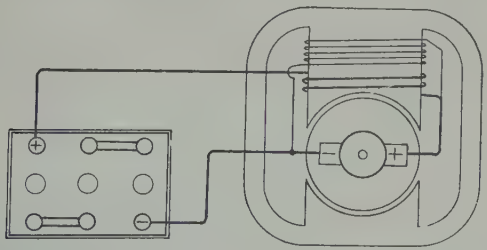


Figure 45.—Connections for a Reversed Series Winding.

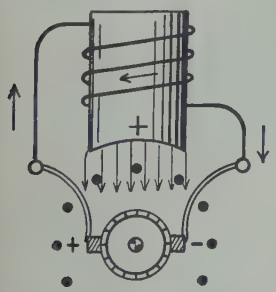


Figure 46.—Field Connection for One Rotation.

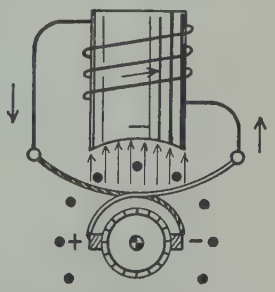


Figure 47.—Field Reversed for Changed Rotation.

water pump represents the dynamo and forces water into a tank representing the battery. From the tank, water discharges through the large right hand pipe, which represents the wires running from the battery to the starter, lights, and ignition system.

It will be seen that as soon as the pump in Figure 48 stops running, the water would flow back out of the tank through the pump were it not for the insertion of the check valve between the two parts. Just so with the electric system, the electric current would start flowing back from the battery through the generator were it not for insertion of an automatic switch between them. This switch is called the reverse current cut-out or simply the cut-out. Its purpose is to prevent discharge of the battery through the genertator armature and the field circuits when the generator is idle or running at a speed too low to charge the battery.

Were the pump in Figure 48 to run at excessive speed there might be too great pressure caused in the water tank and to prevent such a happening there is a by-pass with a spring valve which will release the water pressure when it reaches the maximum safe value. In the electrical system the generator is provided with some means of regulation, either built into the generator or separate from it. This "regulator," whatever its form, prevents the generator's voltage and amperage from reaching a value so high as to damage the storage battery through an excessive charge rate. These dynamo controlling parts will be fully explained in the two following chapters.

STARTING MOTORS

In Figure 49 is the diagram for a lap wound armature into which battery current flows through the positive brush and out at the negative brush. An end view of the same armature is shown in Figure 50, and it will be seen that current flows in one direction, away from the observer, in all the conductors on the

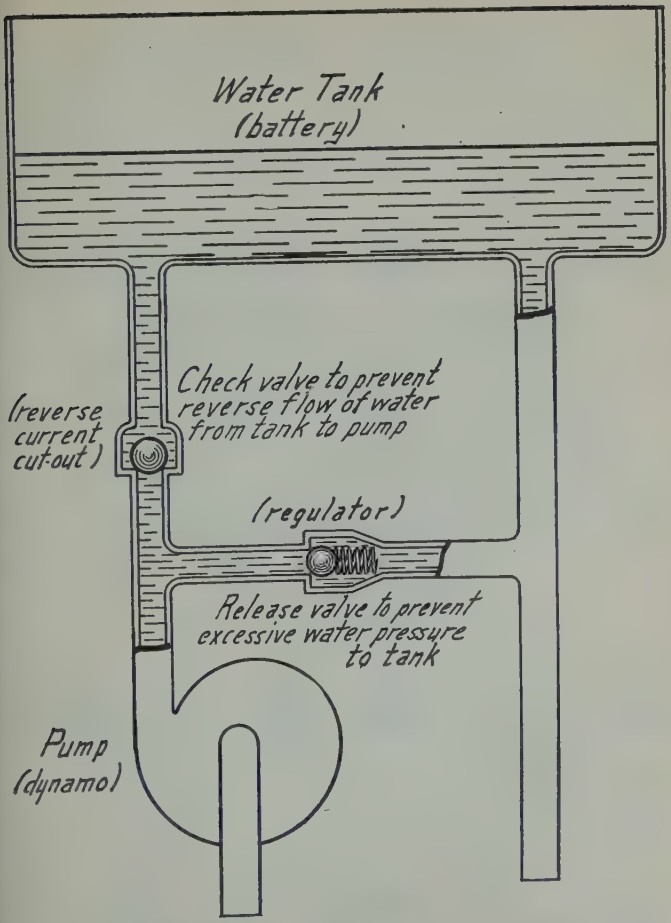


Figure 48.—Comparison of Controls in Water System and Electrical System.

left hand side of the armature core, and flows the other direction, toward the observer, in all the conductors on the right hand side. This will have the same effect on the core as if the current flowed around and around it, making the core an electromagnet with its negative pole at the top and its positive pole at the bottom.

If such an electromagnet were placed between the two poles of another magnet, as in Figure 51, its poles

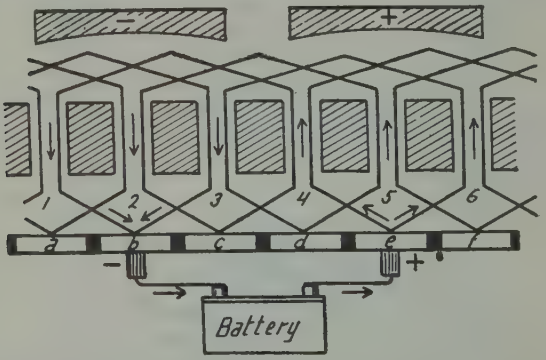


Figure 49.—Flow of Current Through Motor Armature.

would be attracted toward the poles of the other magnet, which may be considered as the field magnet of the machine. The armature core will then tend to rotate and bring the poles together. But, since the commutator and brushes of Figures 49 and 50 will always keep the current flowing in the armature conductors so that the core has a negative pole at the top and a positive at the bottom, the armature poles and field magnet poles can never come together. Therefore, the armature core will continue to rotate as long as the armature conductors and the field wind-

ings continue to receive a current flow. This is the principle upon which an electric motor operates.

Automobile starting motors are always series wound machines and the battery current will flow through the

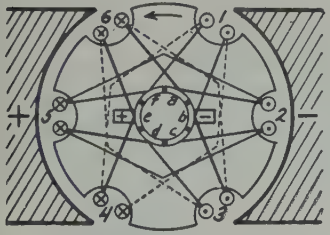


Figure 50.—Current Flow Around Motor Armature.

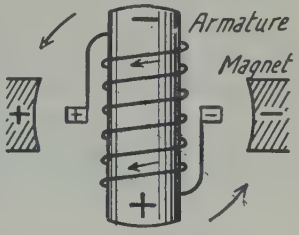
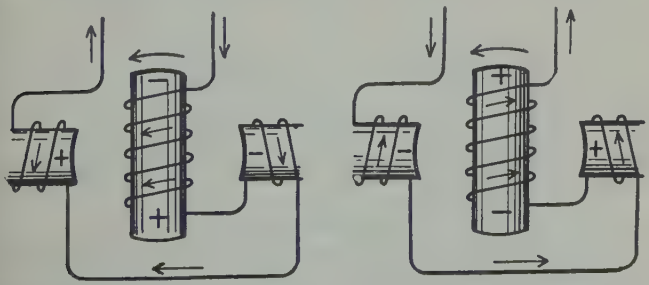


Figure 51.—Principle of the Electric Motor.

motor of Figure 51 as shown in Figure 52, with the armature winding and the field winding in series with each other. If the direction of battery current is re-



Figures 52 and 53.—Unchanged Rotation with Reversal of Current Flow Through a Motor.

versed, as shown in Figure 53, all of the magnet polarities will also be reversed and then, as shown by the arrow in Figure 53, the direction of rotation will remain the same as before. A motor will not

reverse its rotation with a reversal of current. To reverse the rotation it is necessary to reverse the connection of the field circuit to the armature circuit so their relative polarities will be changed.

From the armature diagrams it will be seen that the construction of a starting motor is very similar in principle to that of a generator. The starting motor conductors are made much larger and heavier than those of a generator because of the greater current carried by the motor circuits. Because of the similarity between generators and motors, one ma-

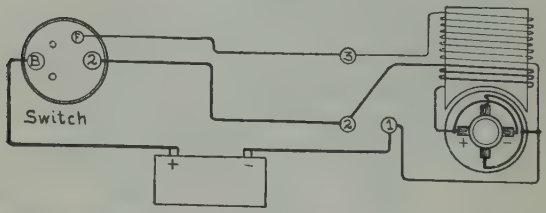


Figure 54.—Connections of Motor-Generator with Single Commutator and Armature Winding.

chine is often used for both generator and starting, the combined unit being called a motor-generator or motor-dynamo.

MOTOR-GENERATORS

Motor-generators, or motor-dynamos, always have a single armature core either with one winding and one commutator or with two windings and two commutators on the one core. These machines must always have a shunt winding for the generator action and a series winding for the starting motor action, and they may also have a regulating winding on the field magnet. A machine with a shunt and a series field

and with a single commutator is shown in Figure 54, while a similar arrangement with the current paths marked is shown in Figure 55.

Referring to Figure 55, with the starting switch *S* closed, current from the positive terminal of the battery flows through the switch and wire *1* around the heavy wire series field, as shown by the arrows, through wire *2* to the brush and commutator, then to the other brush and wire *3*, and back to the battery negative terminal. At *4* the current divides

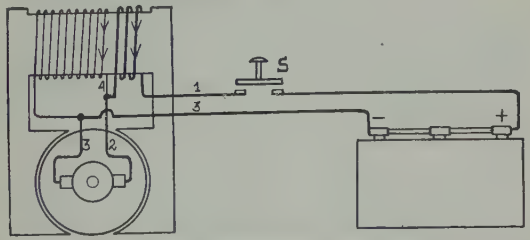


Figure 55.—Motor-Generator with Compound Motor Action and Reverse Series Generating.

and part of it goes through the shunt winding as shown by the arrows, traveling in the same direction around the magnet as in the series winding and thus making a compound wound starting motor. Acting as a generator, current from the right-hand positive brush flows through the shunt winding in the direction of the arrows to the left-hand negative brush. But to get to the battery, current from the right-hand brush must flow from point *4*, in a direction opposite to that of the arrows, to wire *1* and to the battery. It is thus seen that the series field opposes the shunt field while the machine acts as a generator and forms a reversed series dynamo.

In Figures 54 and 55 the starting switch remains closed to allow battery charging current to flow after the machine reaches generating speed and voltage. In Figure 56 is another motor-generator with a cut-out. With the starting switch closed, battery current flows through wire *1* and the series field to the left-hand brush, through the armature to the right-hand brush, then through wire *2* back to the battery. As a generator, current from the left-hand brush goes through the shunt field and wire *4*, through the regulator and wires *5* and *2* to the right-hand brush. Bat-

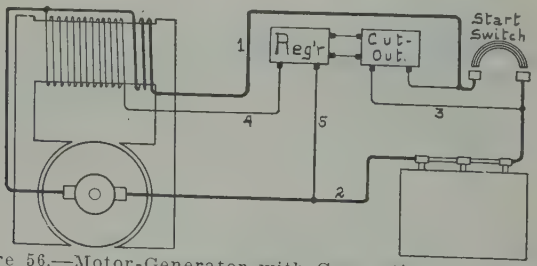


Figure 56.—Motor-Generator with Connections for Separate Regulator and Cut-out.

tery charging current through wire *1* cannot go through the open starting switch, so goes through the cut-out and wire *3* to the battery. The series field again gives reversed series regulation.

A Delco type of motor-generator is shown in Figure 57. This machine has a starting motor commutator *M* and a dynamo commutator *D*. The cut-out switch is hand operated in connection with the ignition switch. While starting, battery current flows through wires *1* and *2*, through the series field, wire *3*, and the brush *S*, used for a starting switch, then to the starting commutator and the starting winding on the

armature, and through wire *4* to ground through which the current returns to the grounded side of the battery. While generating, the field current flows from the generator commutator *D* through the shunt

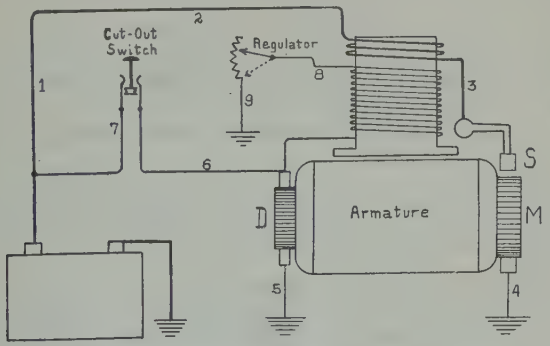


Figure 57.—Motor-Generator with Double Commutator and Two Armature Windings (Delco).

field, wire *8*, the regulator, and wire *9* to ground, where it returns to the grounded side of the commutator. Charging current flows through wire *6*, the cut-out switch, and wire *7* to the battery, returning through the ground connections.

REVIEW OF CHAPTER II

GENERATOR CONTROL—STARTING MOTORS

Field magnet poles carrying windings are called **wound poles**; those without windings are called **consequent poles.**

In a **shunt field winding**, the circuit through the field coils is in parallel or shunt with the armature, also the outside circuit.

In a **series field winding**, the circuit through the field coils is in series with the armature and external circuit.

A **compound field winding** includes both shunt and series coils so connected that they both produce the same polarity in the field magnet.

A **reversed series field winding** includes both shunt and series coils so connected that the series coil opposes the shunt.

If the direction of **rotation of a generator is reversed,** the connection of the shunt field winding to the brushes must also be reversed, after which the brushes will be of the original polarity with the new rotation.

All automobile **starting motors are series wound** machines.

The current through the armature of a **motor** makes opposite poles on the motor armature core at the points midway between the field poles and the attraction between these armature poles and the field causes rotation of the armature.

To **reverse the direction of rotation** of a series wound motor it is necessary to reverse the connections of the series field coils to the brushes. Reversal of current through the motor will not reverse the direction of rotation.

Motor-generators have a single armature core with either one set of windings for both generating and cranking, or two sets, one for each function. They always have a series winding for starting motor action and a shunt winding for generating. They may also have a reversed series winding for regulation.

Motor-generators with only shunt and series field windings generally allow the series coil to act as a reversed series during generating.

CHAPTER III

GENERATOR CONTROLLING DEVICES

All automobile dynamos are primarily shunt wound machines. Plain series wound dynamos are never used and when a series winding is used in connection with the shunt, the series winding is for purposes of control.

In order to make the necessity for controlling methods clear, it is advisable to first consider the shunt wound dynamo under three conditions; first with the dynamo terminals open circuited and not connected to any outside load; second with the dynamo connected to a battery only; and third with lamps added to the dynamo and battery combination.

In this connection it should be noted that the automobile dynamo is a variable speed machine because it is driven directly from the engine through a positive drive which increases and decreases the dynamo speed with every increase and decrease of engine speed.

From the explanation of electromagnetic induction given in preceding chapters, it is plain that the greater the dynamo speed, the faster will the lines of force be cut by the armature coils and the greater will be the voltage produced. This increase of voltage with increase of speed tends to cause a corresponding increase of current or amperage through whatever circuits are connected to the dynamo.

The shunt wound dynamo with its terminals open-circuited is shown in Figure 58 at the left. The com-

plete circuit is shown by the arrows and it is seen that all of the current must pass through the field winding inasmuch as the outside terminals *A* and *B* are not connected to any load. Under this condition the dynamo voltage would build up with exceeding rapidity and the amperage forced through the fields would soon burn out their windings.

In Figure 58 at the right is shown the same shunt

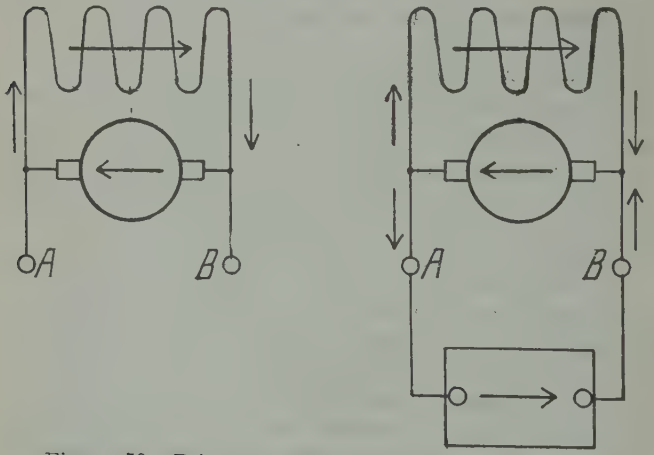


Figure 58.—Principle of the Shunt Wound Dynamo.

wound dynamo connected to a battery. The battery forms a shunt load between terminals *A* and *B* and it is in shunt or parallel with the field winding. From a preceding explanation of shunt circuits it will be recalled that the flow of current through each of the branches of a shunt circuit is in inverse proportion to the resistances of the branches. In the case shown by Figure 58 at the right, the resistance of the bat-

tery is much less than the resistance of the shunt field winding and for that reason most of the current from the armature will go through the battery and but little through the field. If the resistance of the battery is increased, more of the current will be forced back through the shunt field because its resistance remains the same. This increase of field current will increase the number of lines of force that the armature coils can cut and the voltage will be increased by the additional load imposed.

In Figure 59 the shunt dynamo is shown connected to both a battery and a set of lamps. It will be noted

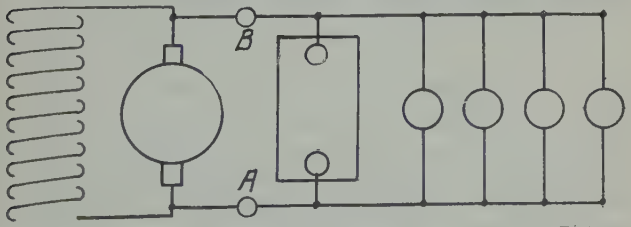


Figure 59.—Shunt Wound Dynamo Connected to Battery and Lamps.

that the lamps are connected in shunt or parallel and that they each form one branch of a shunt circuit. With only the dynamo and battery as in Figure 58 the conditions affecting the dynamo voltage were governed by the battery resistance. If the four lamps shown in Figure 59 are turned on and the current allowed to flow through them the total resistance between the dynamo terminals *A* and *B* will be less than with only the battery in circuit because with shunt circuits the resistance of all of the branches taken together is less than the resistance of any one branch. The more lamps that are turned on, the less will the resistance

across the dynamo become. With a decrease of resistance in the outside circuit, more and more of the dynamo current will pass through it and correspondingly less will remain for the shunt field. An increase of lighting load on a shunt wound dynamo thus decreases the field current and thereby decreases the dynamo voltage and output, while an increase of battery load increases field current, voltage and output.

Placing the battery in parallel with the dynamo and the lamps is said to be floating the battery on the line and under this condition the battery acts as a voltage regulator or stabilizer within certain limits so that the voltage to the lamp lines does not rise much above, or fall far below, the battery voltage.

FACTORS IN OUTPUT CONTROL

The voltage and current of a dynamo are determined by two principal factors; one being the armature speed, the other the field strength. An increase of either speed or field magnetism increases the number of lines of force cut in a given time and therefore increases the voltage, while a decrease in either speed or field strength decreases the voltage and output. Control methods must act to change either the speed or field strength. Direct control of the armature speed was at one time in considerable favor but is no longer used with the newer outfits, so that all of the methods to be considered are methods of controlling the field strength.

Classes of Control.—Any one of three different results may be secured in designing an electrical system. The dynamo may be designed to operate at a constant voltage, and with the same voltage maintained under all conditions the current or amperage

will depend on the resistance or load being carried by the dynamo. With constant voltage the system will always have variable current.

The equipment may be designed to maintain a constant current or amperage flowing from the dynamo to the load circuits. In this case the voltage must vary in order to maintain this constant current against various amounts of resistance. Thus with constant amperage the system will always have variable voltage.

Still other designs, and they are the ones now in most general use, maintain neither constant voltage nor constant amperage, but vary both the pressure and the flow in accordance with the demands being made on the dynamo or in accordance with the speed of the armature shaft.

Changing the Field Magnetism.—All of the control systems in use change the field strength in one or the other of three ways. One way changes the voltage acting on the field windings by connecting the field between one of the main brushes and an auxiliary brush in such a way that a peculiar characteristic called armature reaction is utilized to maintain the desired voltage. This is generally called the third brush system and is now more popular than any other type of control.

A second general class of controls employs a series field winding in addition to the shunt winding and by various means of changing the flow through this series winding and its consequent strength, the dynamo output is controlled within desired limits.

A third general class carries a resistance in series with the shunt field circuit and by any one of a great many different devices, the amount of this resistance is varied or else the time during which the resistance

is in the field circuit is varied; in either case the field magnetism being governed to suit the requirements to be met. In some cases the field resistance consists of a coil of resistance wire so connected that it is normally short circuited with reference to the field; then when the field strength is to be reduced, the resistance coil is placed in series with the field to reduce the flow through the windings. This is shown in Figure 60 at the left. With the resistance in circuit, current flows through field and resistance in series. Under ordinary conditions the resistance is short circuited, but when the speed of the dynamo rises sufficiently, the short circuit is removed temporarily and the output is held within the desired limits by the reduction of field strength caused by the resistance.

In other designs the resistance may consist of a rheostat as shown in the center of Figure 60. The rheostat arm is moved from point to point by some automatic means in order to insert or withdraw resistance in the field circuit and thereby control the field current and magnetism.

Another type of field resistance is shown at the right of Figure 60, this consisting of a series of carbon or graphite disks placed flat against one another. Pressing the disks tighter together reduces their resistance, while allowing them to separate loosely increases their resistance. Various automatic means can be employed to vary the pressure on the carbon pile.

THIRD BRUSH CONTROL

Armature Reaction.—Considering a dynamo as shown in Figure 61 at the top in which the fields are magnetized but in which the armature is carrying no current, there will be a flow of magnetic lines of force

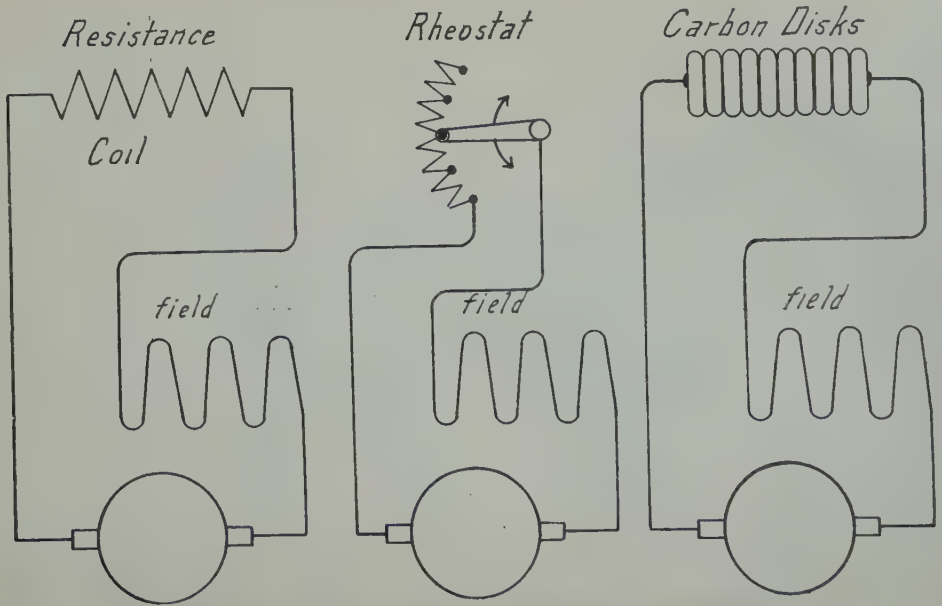


Figure 60.—Methods of Introducing Shunt Field Resistance.

straight across from the positive pole to the negative with the lines running straight through the iron of the armature core.

Again considering a machine as at the center of Figure 61 in which one of the armature coils is carrying current but in which the fields are not magnetized,

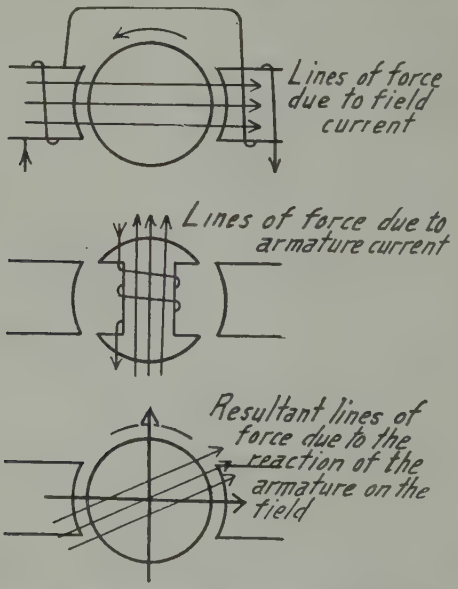

Lines of force due to field current
Lines of force due to armature current
Resultant lines of force due to the reaction of the armature on the field

Figure 61.—Lines of Force of Fields and of Armature.

the armature core is made a magnet or the coil may be considered as a solenoid. Lines of force then flow through the armature coil and make the core magnetic. The lines of force in the field resulting from the action of both poles and armature are shown at the bottom of Figure 61.

With the dynamo in actual operation both of the magnetic fields will be present. The flow of lines of force in the armature will react on the flow of lines of force from the field poles and the result will be a flow of lines of force as shown in Figure 62. The armature reaction will distort the normal field so that there will be a crowding of the lines of force toward the side of the pole piece that the armature core is traveling away from, this being called the trailing side

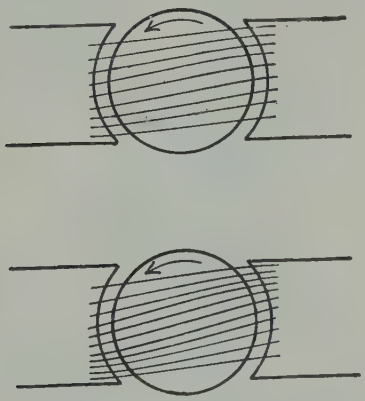


Figure 62.—Distortion of Lines of Force by Armature Reaction.

of the pole piece. There will be a corresponding reduction of the number of lines of force at the side of the pole piece which the armature approaches in its direction of rotation. The effect is similar to the result that would be caused by the armature's carrying the lines of force part way around with it.

At low speeds there is little voltage and current in the armature and but few lines of force are formed in it. The reaction is therefore weak and the field is

distorted comparatively little as at the top of Figure 62. As the dynamo speed and the armature current increase, the effect of the reaction is increased as at the bottom of Figure 62.

Figure 63 shows the method of connecting the field winding between one of the main brushes *B* and the third brush or regulating brush *R*. In the ordinary shunt wound machine the field would be connected between brushes *A* and *B*. The voltage acting on the field winding is then seen to be the voltage between brushes *B* and *R* and the position of *R* will now be considered.

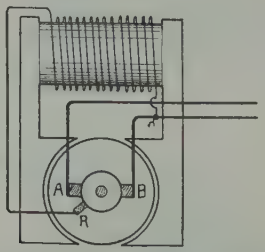


Figure 63.—Dynamo With Third Brush Regulation.

In the upper drawing of Figure 64 the lines of force pass straight through the armature as at low speeds, while in the lower drawing they are distorted as at high speeds. The active conductors on the armature are those cutting the lines of force and they are shown shaded at *M* and *N*, while inactive conductors are shown as white circles. The voltage at the main brushes; *A* and *B*, is proportional to the number of active conductors between them, which number will be seen to be the same under both conditions.

The field winding is connected between the main

brush B and the third brush R and the voltage acting on the field will be proportional to the number of active conductors between them, and the number of these active conductors will be seen to be the same under both conditions.

In the upper drawing the number of active con-

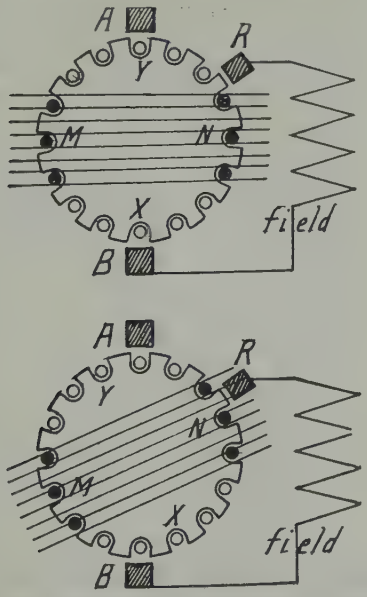


Figure 64.—Effect of Field Distortion on Armature Voltage.

ductors between the brush R and brush B is seen to be the same as between main brushes A and B. The voltage on the field will then be the same as that across the main brushes. With the field lines of force distorted as in the lower drawing, the active conductors have moved with the lines of force so that the number

of active conductors between R and B has become less and the voltage on the field windings has thus been lowered. The higher the armature speed the greater will be the distortion and movement of the active conductors and the lower will the field current become, thus counteracting the increase of speed.

At low speeds the output of the dynamo is little affected by armature reaction and the voltage and amperage increase with the speed. As the reaction becomes stronger and stronger with increase of speed,

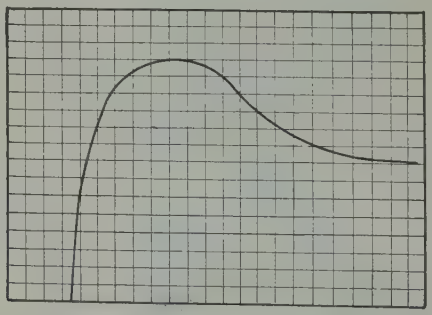
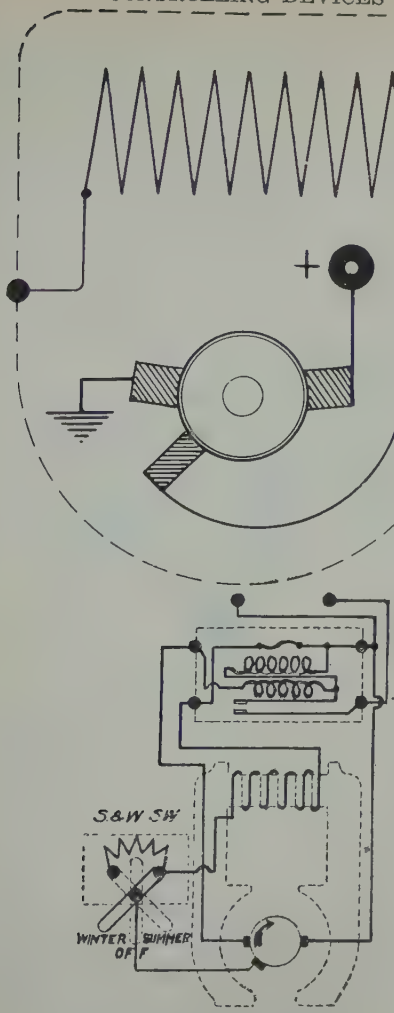


Figure 65.—Typical Output Curve of Third Brush Dynamo.

the reduction in field strength begins to overcome the effect of increased speed and the output of the dynamo stops rising as shown in Figure 65. At still higher speeds the field is so far reduced in strength that the output of the dynamo begins to decline as shown by the end of the curve in Figure 65. Third brush regulation thus allows a rather quick rise to maximum output and the maximum output is reached at comparatively low speeds. At all higher speeds the output is reduced. The exact form of the output curve depends



Figures 66 and 67.—Third Brush Dynamos.
(Delco and Remy)

on the proportioning of the windings and the position of the brushes. Applications of the third brush principle are shown in Figures 66, 67 and 68. In Figure 67 is shown a summer and winter switch for changing the field strength and dynamo output to suit the seasons. Third brush regulation belongs to the variable

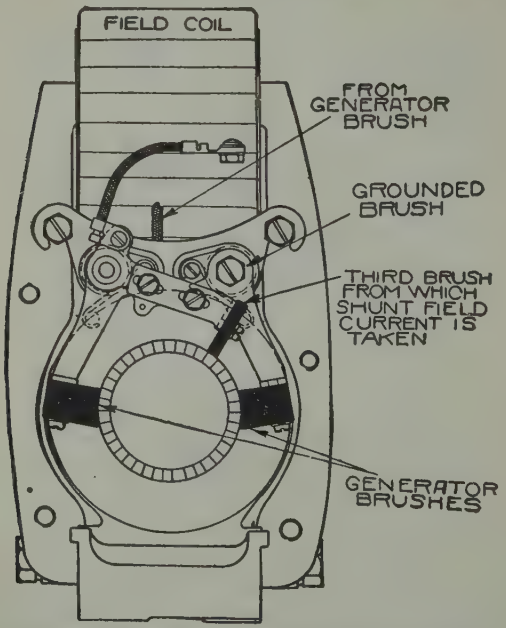


Figure 68.—Third Brush Motor-Dynamo. (Delco)

voltage and variable current class of control systems. At the present time, the majority of cars are fitted with third brush dynamos because they do not easily get out of order, and because of their simplicity they are easily manufactured.

REVERSED SERIES CONTROL SYSTEMS

Among the variable voltage and variable current systems, those using reversed series fields use the load current for control. The principle upon which this field winding system operates has been described in Chapter II, and a lengthy description is therefore unnecessary at this time. The application of this method of regulation in one type of Auto-Lite dynamo is shown in Figure 70. This machine carries two

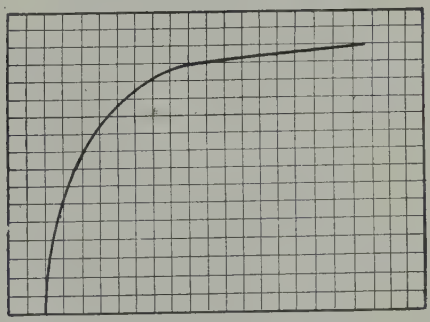


Figure 69.—Output of Dynamo Having Gradual and Continuous Increase (Reversed Series).

windings on each of the field magnet poles, one winding being the usual shunt and the other one being a series coil through which the current, passing from dynamo to battery, flows in a direction the reverse of that taken by the current passing through the shunt coils. From the lower brush, which is positive, current passes to both coils on the lower pole piece, part passing through the shunt field in such a direction that this pole end is made positive. This current is then carried to the upper shunt field winding and passes around this upper pole piece in such a direction that

its end is also made positive. The consequent poles thus formed at either side of the armature are therefore negative.

The portion of the current from the positive brush that is not required for the shunt field, passes around

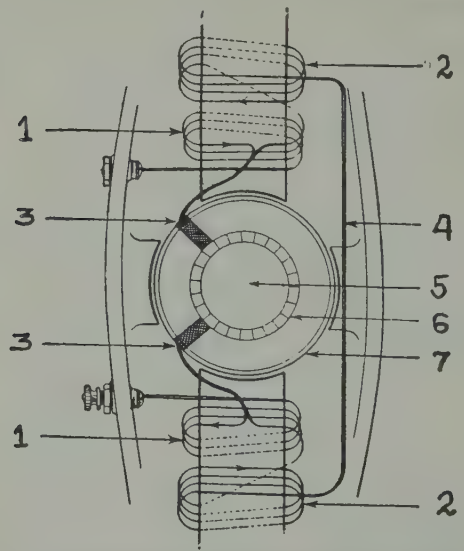


Figure 70.—Dynamo Having Reversed Series Regulation (Auto-Lite).

1—Series Field Windings.
2—Shunt Field Windings.
3—Brushes.
4—Connection for Shunt Windings.
5—Dynamo Shaft.
6—Commutator.
7—Armature.

the lower pole piece in a direction that tends to oppose the shunt winding and to make this pole end of less strength. After passing around the magnet, the current is led to the lower terminal and then to the battery. The current returning from the battery to the

upper dynamo terminal, comes into the upper series winding and passes around the magnet in a direction that tends to weaken this upper pole, thus opposing the shunt winding. Having traveled around the windings, the current joins with that from the upper shunt coil and is led to the negative brush. While this exact method of winding is not always followed, the principle is the same in all applications of this method, that is, to cause the charging current passing around

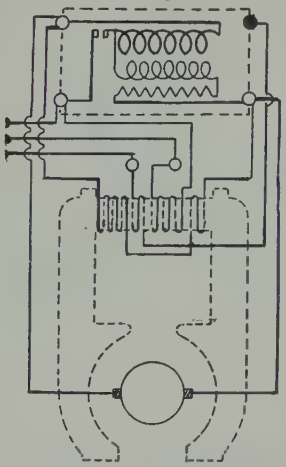


Figure 71.—Remy Reversed Series Dynamo, Model "M."

the series windings to oppose the effect of the shunt winding.

With some applications of the reversed series system, an additional field winding is used through which the lamp current flows in such a way that this extra field assists the shunt winding and opposes the reversed series winding. Figure 71 shows one method of using three field windings, while Figure 72 shows

another design and indicates the purposes of the three fields. The lamp lines are connected to terminal 2 and whenever lamps are lighted the lamp field acts to reduce the effect of the series field and allows the

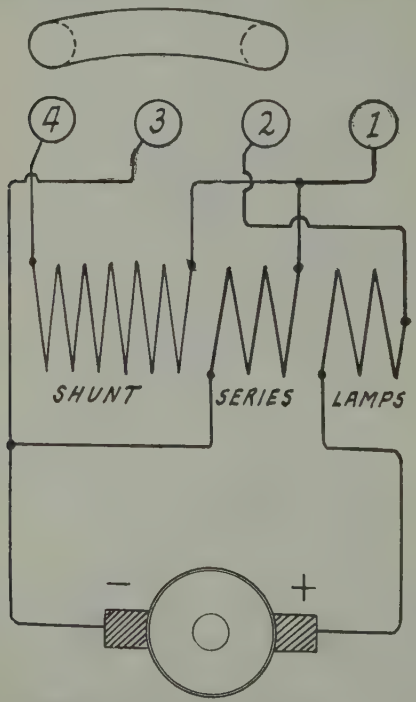


Figure 72.—Esterline Dynamo.

increased dynamo output to carry the lamp load.

Some of the older Westinghouse systems used a connection shown in Figure 73 in which the charging current flows from the positive brush to ground, then

to the battery, through the battery and back to terminal *B*. Then passing through the reversed series field winding, this charging current returns to the negative brush. Lamp current is taken off at terminal *L* and inasmuch as the lamp portion of the load is thus connected directly between the terminal *L* and the brush, it does not come from the battery and does

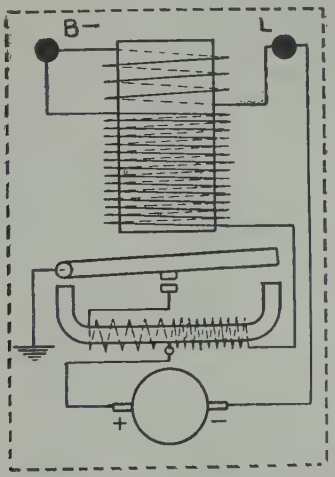


Figure 73.—Reversed Series Dynamo. (Westinghouse)

not affect the series field. Turning on the lamps increases the dynamo output.

A somewhat novel application of reversed series control is shown in Figure 74 in which the series winding is marked "DIFF" for differential. The reversed series winding is sometimes called a differential winding and in some cases it is called a bucking coil. The vibrating relay shown at the top of Figure 74 car-

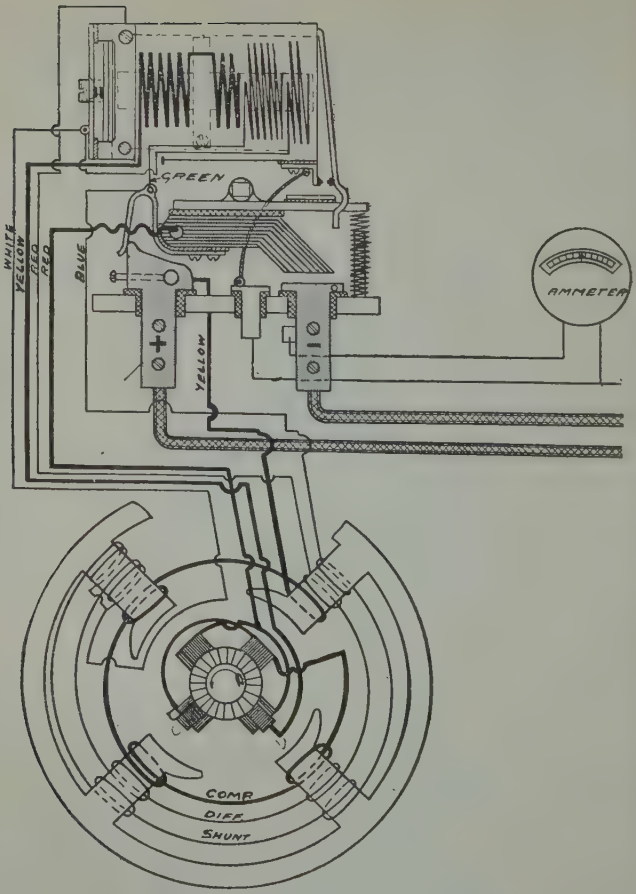


Figure 74.—Jesco Motor-Dynamo.

ries a high resistance in parallel with the reversed series winding but this resistance is normally short circuited by the relay contacts. With the contacts open the field current is forced to pass through the reversed series winding because the winding has a lower resistance than the resistance coil of the relay.

CONSTANT AMPERAGE SYSTEMS

Control methods that make use of the current flowing to the load circuits in order to maintain that cur-

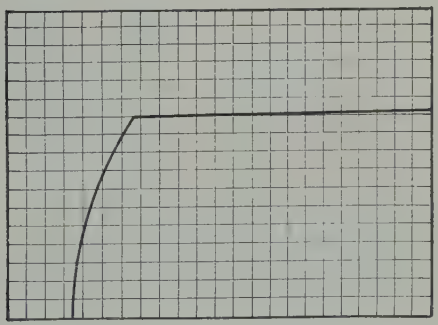


Figure 75.—Output of Dynamo Having Constant Amperage Regulation.

rent at a constant value in amperes, regardless of dynamo speed or of external resistance, are described under this head. The characteristics of the output secured with such control are shown by the curve in Figure 75 in which it is seen that the rise in voltage and current is in proportion to the speed until the regulator comes into action, after which the output in amperes is practically constant for all higher speeds. Many such systems make use of a regulating device comprising an electromagnet whose strength

increases with increase of dynamo voltage and which causes a high resistance to be temporarily inserted in the shunt field circuit when the dynamo speed becomes high enough to cause excessive voltage and therefore excessive amperage. The principle of such

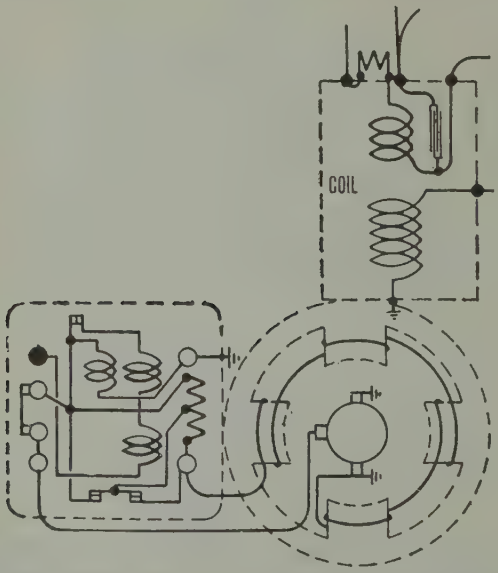


Figure 76.—Remy Dynamo and Constant Current Control.

a mechanism is shown in Figure 77. The three dynamo terminals are marked *F*, *A* and *D*; *F* being attached to one end of the shunt field winding, *A* to one of the dynamo brushes, and *D* to the other brush and the remaining end of the field winding. The regulator consists of the magnet *M* around which current from

dynamo terminal *A* flows through the wire *1* on its way to the battery. It will be seen that this magnet will become stronger as the amperage passing from the dynamo to battery increases. The armature of this magnet is held away from the core by the spring *B*, and with the armature in this position, the contacts *C* are closed.

Current for the shunt field leaves the dynamo at terminal *A*, passing through the wire *1* to the contacts.

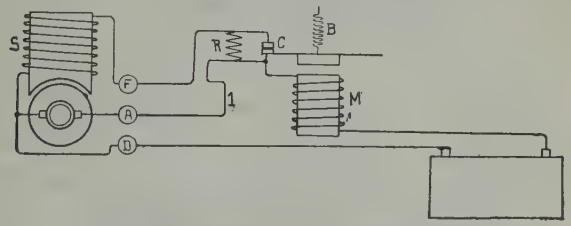


Figure 77.—Electromagnetic Regulator for Constant Amperage.

This current does not flow through the coil *R* because this coil is made from wire with a very high resistance, but the current takes the path of low resistance through the contacts. From the upper contact the field current passes to dynamo terminal *F*, through the shunt field winding and to the left-hand brush. As long as the amperage flowing to the battery around the magnet *M* is not great enough to cause the magnet to overcome the tension of the spring *B*, the above conditions hold true. The spring tension is set at such a point that when the desired maximum amperage of charging is reached, the magnet attracts its armature and the contacts *C* open. The field current can no longer pass through the contacts, but must take the path through the resistance coil *R*. This

resistance allows but a small current to pass through the field, with a consequent reduction in field strength and dynamo output. The decreased output results in a lessened flow around the magnet *M*, and the contacts are again closed by the tension of the spring *B*. In practice this opening and closing of the contacts is so rapid as to be almost imperceptible to the eye, and the field current is maintained at such a strength that

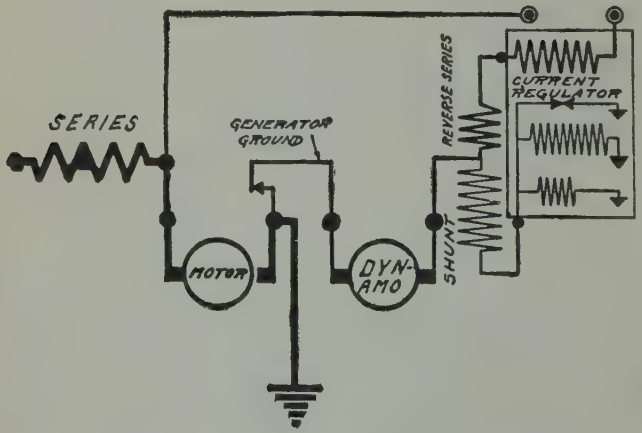


Figure 78.—Reversed Series Motor-Dynamo With Current Control Attached to Dynamo Fields. (Delco)

the dynamo output cannot exceed the maximum for which the spring tension is set, regardless of dynamo speed. Increasing the spring tension or increasing the air gap between magnet core and armature will raise the amperage that the dynamo will give, while decreasing the spring tension or lessening the air gap will result in a lower amperage for charging.

Systems using the vibrating form of regulator practically always make use of an electromagnetic cut-out with it. The two units are combined in one housing and called a controller. The controller may use two

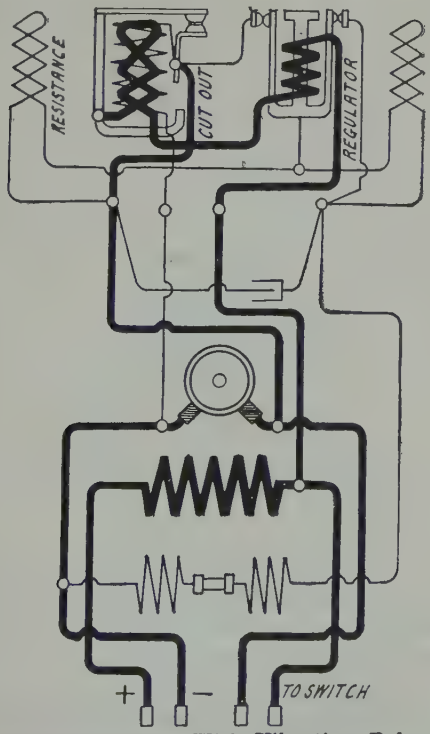


Figure 79.—Motor-Dynamo With Vibrating Relay Controls. (North East)

magnets, one for the regulator and one for the cut-out, or may use but one magnet with two windings for both functions. Such a combination is illustrated in

Figure 80. The single magnet is so arranged that it will attract the right-hand armature for cut-out action and the left-hand armature for regulator action. This magnet carries a fine wire winding which is the shunt coil for the cut-out action, and a second coil of heavy wire which forms the series winding for the cut-out and the main winding for the regulator in a way similar to that of the type shown in Figure 77. The field resistance is connected between the left-hand regulator contacts. The four terminals used with this type of controller, are *F, A, DB* and *B*.

The action is as follows: When the dynamo is idle,

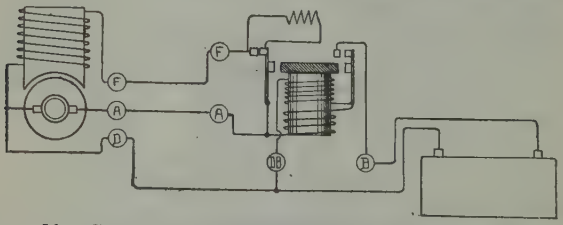


Figure 80.—Controller Connections with Magnetic Cut-Out and Constant Amperage Regulation.

the cut-out contacts are open and the regulator contacts are closed. When the dynamo generates a difference of voltage, current flows from dynamo terminal *A* to controller terminal *A*, through the heavy coil on the magnet, then through the fine wire coil to terminal *DB* and to dynamo terminal *D*. The field circuit is completed from dynamo terminal *A* to controller terminal *A*, through the closed regulator contacts at the left and from terminal *F* to the dynamo field terminal *F*, then through the shunt field and to the left hand brush. The flow of current around the magnet causes the cut-out contacts at the right to close when the

dynamo voltage is high enough to charge the battery. Current from dynamo to battery passes through the heavy winding to the cut-out contacts which are closed,

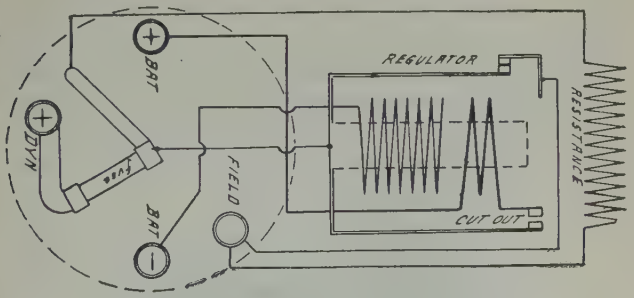


Figure 81.—Allis-Chalmers Controller.

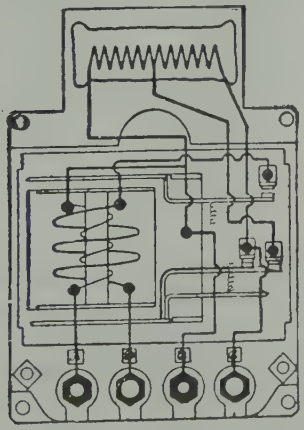


Figure 82.—Ward Leonard Controller.

then to controller terminal *B* and to the battery. When the amperage through the heavy winding of the magnet reaches the desired maximum, the regulator contacts at the left are drawn apart. Field current

then passes through the resistance and regulation takes place as described when no cut-out is used.

In Figure 81 is shown a controller using one magnet for both regulator and cut-out and showing the connections made from the control parts to terminals on the round cover of the instrument. Figure 82 shows another controller with one magnet and with the parts arranged somewhat differently. In Figure 82 the cut-

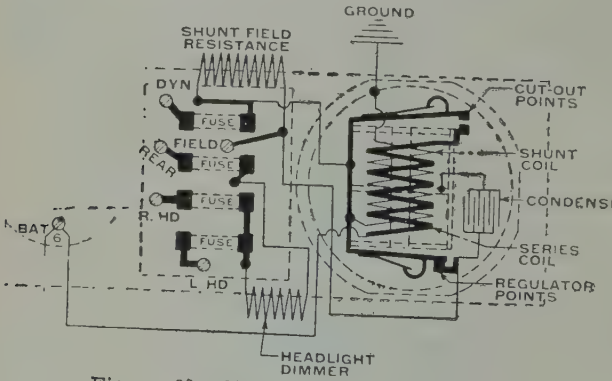


Figure 83.—Simms-Huff Dash Controller.

out contacts are near the top and the two pair of regulator contacts are below. The left hand terminal leads to dynamo and battery, the next one to battery, the third one to the dynamo armature and the right hand terminal to the shunt field.

Figure 83 shows a controller having a single magnet for regulator and cut-out and shows the use of a condenser between the regulator contacts to prevent arcing as these contacts open and close. This unit is mounted on the cowl board and some of the lamp and fuse connections are also shown.

Figure 84 shows a constant amperage controller with two magnets, the left-hand magnet and its contacts being for the cut-out, while the right-hand magnet and contacts are for the regulator. The field resistance is between the magnets. Reading from left to right, the controller terminals connect respectively to ground, battery, generator shunt field, and generator armature.

A Gray & Davis constant current controller is shown in Figure 85. Field current flows through the

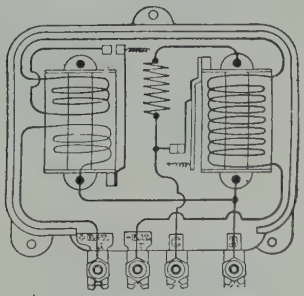


Figure 84.—Constant Amperage Controller (Ward Leonard "E").

controller resistance from center terminal *F* to the right-hand terminal *F* when the regulator contacts are open. With these contacts closed they short circuit the resistance. Battery charging current flows into terminal *A*, through the series cut-out winding and contacts to the battery through terminal *B*. The lamp line is connected to terminal *L* and when the lamps are turned on, the current flowing to them passes through only a part of the magnet winding, the remainder going on to the battery terminal *B*. This reduction of current through the magnet wind-

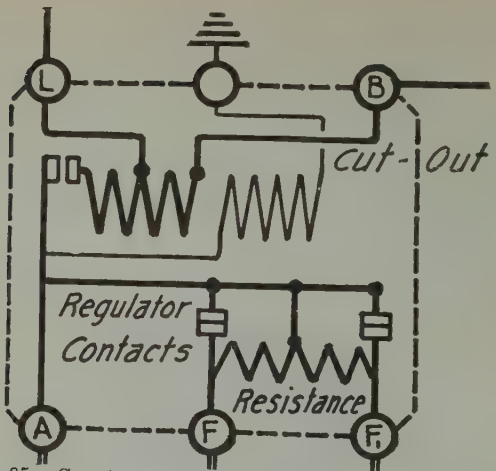


Figure 85.—Constant Current Regulator with Load Control (Gray & Davis).

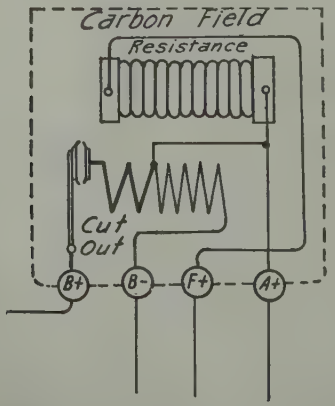


Figure 86.—Controller with Carbon Disc Resistance (U. S. L.)

ing allows the regulator contacts to remain closed for a longer time and the generator output is increased as long as the lamps are lighted.

A U. S. L. controller using carbon discs for the field resistance is shown in Figure 86. The discs are normally held together by a spring so that there is little resistance between them. The regulator magnet

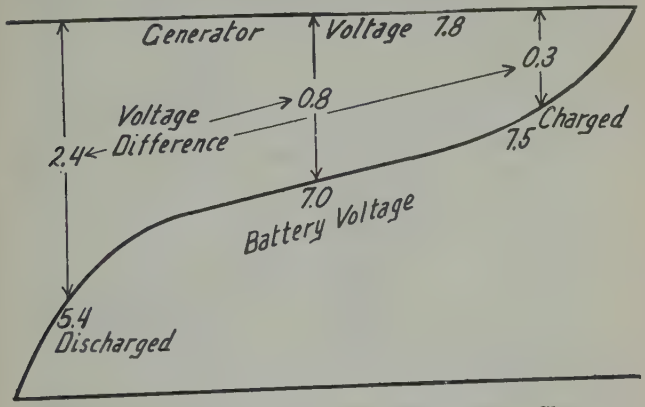


Figure 87.—Rise of Battery Voltage During Charge.

acts against this spring and as the magnet becomes stronger with increase of charging current through it, the discs are allowed to separate and increase the field resistance. Terminals marked *B* connect to the battery, terminal *F* connects to the generator field, and terminal *A* connects to the generator armature.

CONSTANT VOLTAGE CONTROL

As shown in Figure 87, the voltage of a battery increases during charge so the voltage at full charge is much higher than the voltage of a battery that is

discharged or partially discharged. If a dynamo is operated in such a way that the voltage generated will remain constant at one value over practically the whole range of armature speed it will be seen that the difference in voltage between the dynamo and battery will depend not only on the dynamo but also on the voltage of the battery at any particular time. With a nearly discharged battery of low voltage, the difference between dynamo and battery will be compara-

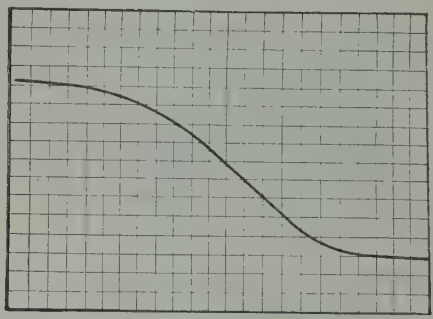


Figure 88.—Output of Dynamo Having Constant Voltage Regulation.

tively great, while with a battery that is nearly charged and of correspondingly high voltage, the difference will not be so great. For this reason the flow from the dynamo to a discharged or partly charged battery will be caused by a comparatively large difference of voltage, and this flow will be relatively great in amperage. The flow from the constant voltage dynamo to a battery that is nearly or fully charged and of correspondingly high voltage will be caused by a smaller difference in pressure, and the amperage will therefore be relatively small. This

action gives what is known as a "tapering charge," that is, a charge whose amperage becomes less and less as the battery becomes charged and as the battery voltage increases. The characteristics of such regulation are shown in Figure 88, in which the percentage of battery charge from zero to full charge is shown from left to right while the amperage or voltage difference is shown by the horizontal lines and decreases from top to bottom. In this connection it should be borne in mind that the specific gravity of the battery electrolyte increases with increase of battery voltage, and it may therefore be stated that the rate of charge in amperes will be greater at low specific gravities than at high.

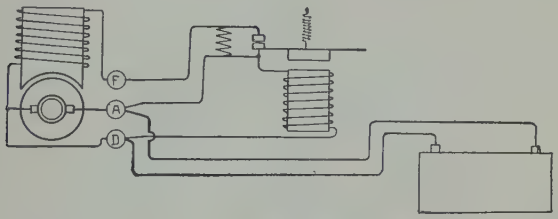


Figure 89.—Vibrating Relay for Constant Voltage.

Vibrating Relay Control.—Figure 89 shows the connections used for constant voltage control when using a vibrating relay whose contacts leave a resistance in the field circuit when they are open and which short circuit this resistance when they are closed. The magnet winding is connected between the dynamo brushes. In the system shown by Figure 89, this connection runs from the right hand brush to terminal *A*, then through the magnet winding and back to terminal *D* and the left hand brush. It will be found

that otherwise the connections are very similar to those shown in Figure 77 for constant amperage control with a vibrating relay. With constant amperage control the magnet carries the battery charging current, while for constant voltage the magnet winding is a shunt of the generator armature circuit.

Westinghouse Regulator.—The internal circuits of a Westinghouse constant voltage regulator with a cut-

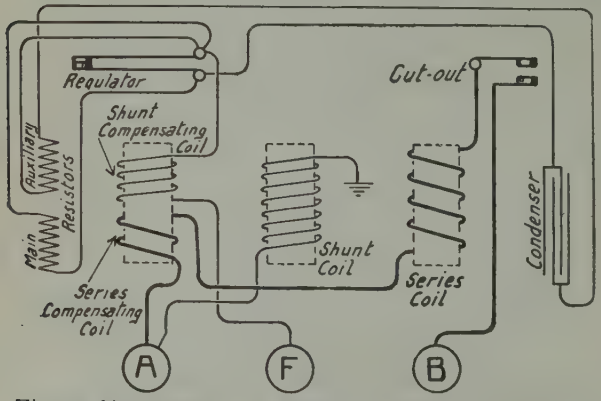


Figure 90.—Circuits of Constant Voltage Controller (Westinghouse).

out are shown in Figure 90 and the appearance of the unit with the cover removed is shown in Figure 91. In Figure 92, which is a rear view, may be seen the form of three-pole magnet used with all Westinghouse controllers of this type, but the windings in Figure 92 are not exactly the same as in Figure 90.

Referring to Figure 90 it will be seen that generator current returning from the battery through terminal *B* goes through the cut-out contacts, the series coil, the series compensating coil, and to the generator

through terminal *A*. The shunt coil is connected between the ground on the case and terminal *A* and since the positive side of the generator is grounded, this connects the shunt coil between the generator brushes for cut-out action.

The main resistor is connected between the regulating contacts and supresses the spark when these

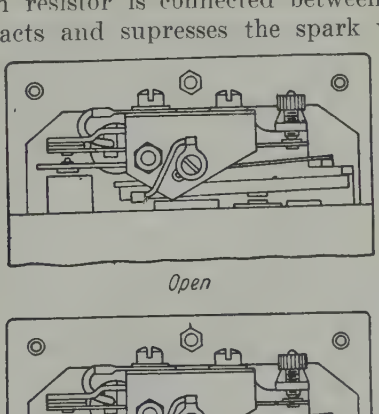


Figure 91.—Adjustments of Westinghouse Controller. Cut-out Shown Open and Closed.

contacts separate. Connected between the regulator contacts is also a condenser to absorb the spark as they separate and in series with this condenser is the auxiliary resistor which cuts down the condenser discharge when the contacts again close and thus prevents any welding effect that might be caused by this condenser current through the contacts. Both resistors are wound on a brass strip.

There is also a shunt compensating coil connected in series with the generator shunt field between the regulator contacts and terminal *F*. This coil is for

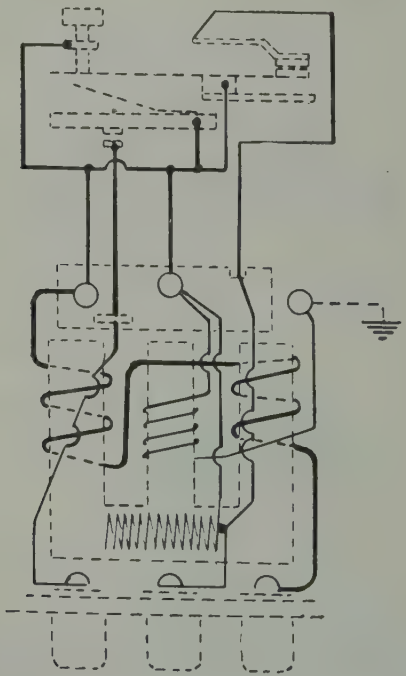


Figure 92.—Construction of Westinghouse Controller.

the purpose of increasing the sensitiveness of the regulator magnet. This shunt compensating coil opposes the effect of the series compensating coil and the shunt coil.

The series compensating coil performs two functions. Since this coil is in series with the main series coil at the left, it carries both the charging current and the reverse current from the battery before the cut-out opens. When the charging current is very high this series compensating coil acts with the shunt coil in its effect on the regulator in keeping the voltage down. When the reverse current from the battery flows back, this series compensating coil indirectly assists the main series coil in killing the effect of the shunt coil, so that the magnet's strength is fur-

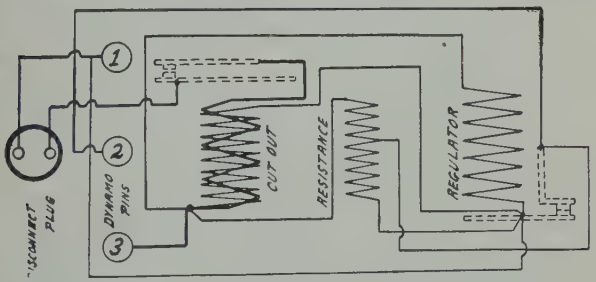


Figure 93.—Bijur Constant Voltage Controller.

ther reduced to allow the cut-out spring to open the cut-out contacts.

The regulator spring tension is adjusted by turning the screw shown at the upper right-hand side of the controller in Figure 91. Increasing the tension raises the voltage, lessening the tension lowers the voltage. The cut-out is adjusted by bending the two extending prongs of the brass support at the end of the cut-out armature toward the right-hand side. The outer prong controls the armature gap and the inner prong controls the spring tension. The cut-out contacts are shown open and closed in Figure 91.

Bijur Regulator.—The internal connections of the Bijur constant voltage regulator with cut-out are shown in Figure 93. From the disconnect plug at one end of the controller, wires run to the battery lines. Terminals *1*, *2* and *3* represent pin connections that enter holes in the generator housing on top of which this regulator is mounted. Pin *1* connects with the generator brush and armature, *2* connects with the generator shunt field, and *3* connects with the other generator brush and the other end of the shunt field. The regulator magnet and contacts are shown at the right-hand end, the cut-out magnet and contacts at the left-hand end, and the field resistance is shown between the magnets.

On some of these regulators there is no connection from the center of the resistance to the regulator contacts, the whole resistance being between the contacts. Most of the regulators have, however, been changed to conform with the diagram in Figure 93.

Current for the cut-out shunt winding enters the regulator through pin *1*, goes over to the common connection near the regulator contacts, then back to the upper end of the cut-out shunt winding, through this winding and back to the other generator brush from pin *3*. Battery charging current from pin *1* goes to the disconnect plug and the battery, then from the battery through the other side of the disconnect plug, the cut-out contacts and cut-out series winding, back to the generator through pin *3*. The regulator magnet winding is connected between the generator brushes by the lines from the winding to pins *1* and *3*. The generator shunt field current through pin *2* goes through the regulator contacts and back to the generator through pin *1*. With the contacts open, this

field current must pass through the field resistance which is connected in parallel with the contacts. The connections for this same type of regulator and cut-out, when built into the generator, are shown in Figure 94.

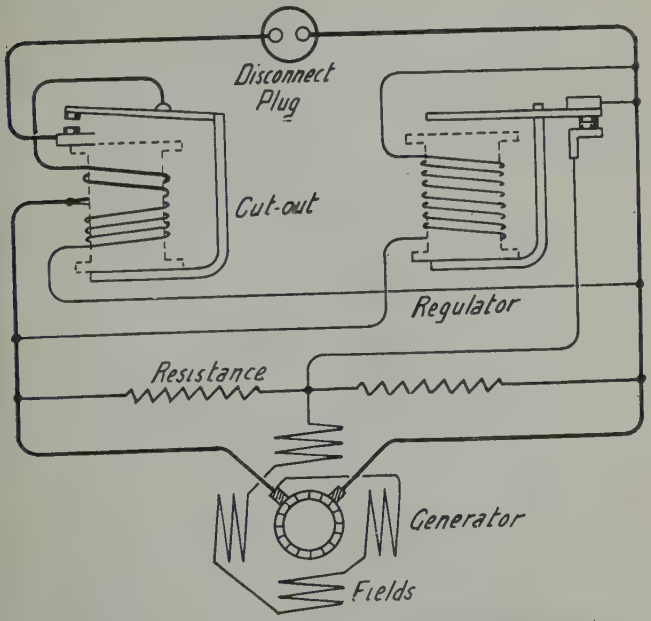


Figure 94.—Bijur Controller Mounted in Generator.

Delco Regulator.—A Delco voltage regulator used in connection with a third brush generator is shown in Figure 95. On the right-hand side is a standard cut-out with its voltage (shunt) coil and its current (series) coil on the magnet core. One side of the generator is grounded and the cut-out shunt coil is

connected between the generator brushes through terminals *G* (grounded) and *A* (generator armature).

Until the battery becomes almost fully charged there is not enough current sent through the voltage coil of the regulator to separate the contacts. Consequently, with a battery not fully charged, the generator acts only as a third brush machine. When the battery specific gravity reaches about 1.250, and at all points above this, there is enough current through the regulator to make the contacts vibrate. With the contacts closed, the field current flows from terminal *F* through them and back to the generator through terminal *A*. With the contacts separated, the field current must pass through the reverse coil and the non-inductive coil, which are also on the regulator magnet. These two coil windings form the field resistance.

The reverse coil winding has many turns of fine wire running around the core in the opposite direction from the voltage coil. The non-inductive winding has half its turns wound in each direction around the magnet, its purpose being to prevent sparking at the contacts.

The third brush of the generator is adjusted with the regulator contacts held together or with a jumper wire between terminals *A* and *F*. With a warm generator and fully charged battery the third brush is set for 13 to 14 amperes at 20 to 25 miles an hour. The jumper wire between *A* and *F* is then removed or the contacts are released and the regulator spring tension adjusted so that the generator output does not go above 8 to 9 amperes.

Constant Speed Control.—Some of the older generators fitted a friction clutch between the generator

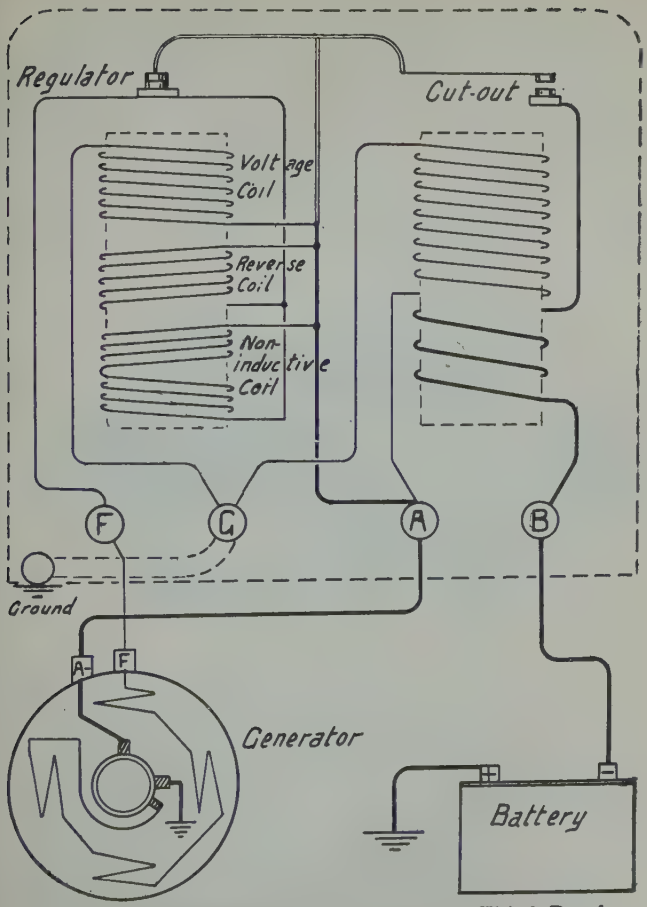


Figure 95.—Delco Voltage Control with **Third Brush** Generator.

armature shaft and the engine driving shaft. Centrifugal weights which are opposed by a spring operate the clutch shoes so that they are released at all speeds above that with which the generator produces the desired voltage. A Gray & Davis constant speed generator is shown in Figure 96.

There were several designs of constant speed generators built during the earlier development of automobile lighting systems, but at present this construction is not being used.

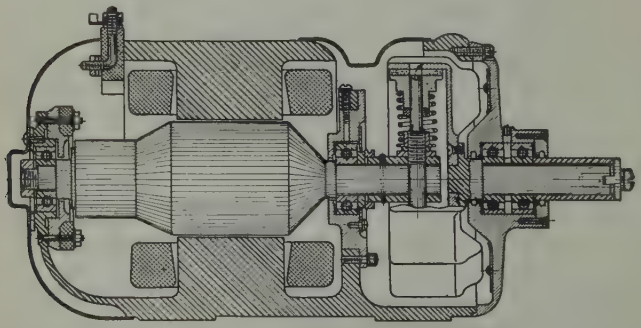


Figure 96.—Slipping Clutch Speed Control (Gray & Davis).

Cam Regulator.—In Figure 97 is shown one construction of a constant voltage regulator which makes use of the speed of the armature shaft. A resistance is connected in series with the shunt field and this resistance is short circuited by the contact points shown. A slightly eccentric cam is carried by the end of the armature shaft and on this cam rests a bumper block which, being carried by a spring arm, tends to follow the cam contour. One contact is attached to this bumper block and moves with it. A second contact is held down on top of the first one by a second spring

arm, and the upper contact would therefore tend to remain in contact with the lower one. The upper contact is also acted upon by an electromagnet connected across the dynamo brushes so that it is acted upon by the dynamo voltage and this electromagnet acts to draw the upper contact up and away from the lower one, the force of this withdrawal and the distance that

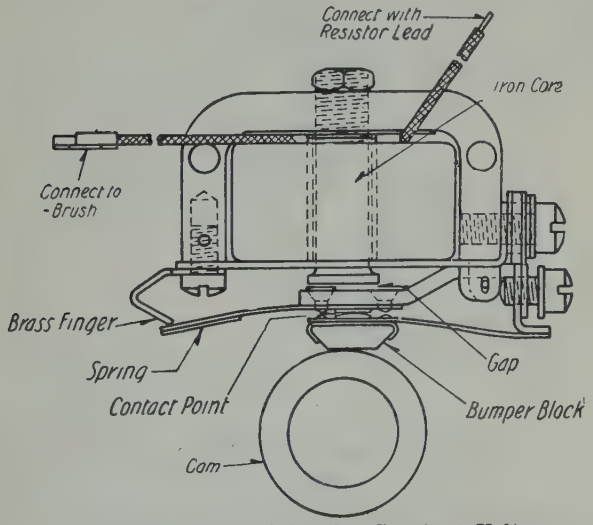


Figure 97.—Cam Regulator for Constant Voltage. (Westinghouse)

the contacts might be separated being determined by the dynamo voltage and the consequent strength of the magnet. During the time the contacts are together the resistance does not affect the field circuit, but while they are apart the resistance is inserted.

With increase of dynamo speed the upper contact is drawn away from the lower one so that the time during

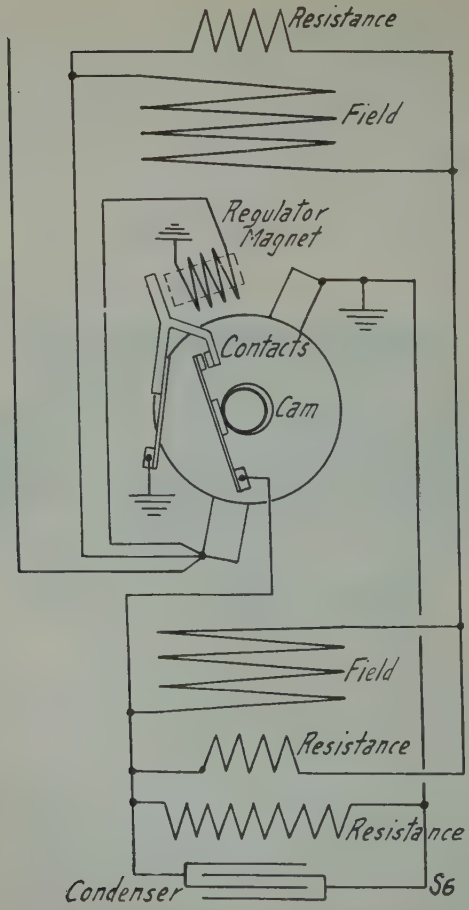


Figure 98.—Cam Regulation for Constant Voltage.
(Splitdorf)

which they are together is reduced. Thus, increased voltage increases the time during which the resistance acts and the voltage remains nearly constant. In Figure 98 is shown a Splitdorf application of cam regulation using the same principle.

CONTROL BY TEMPERATURE

Thermostat System.—Due to current flow a dynamo becomes heated after running and this fact has been utilized in several Remy systems to effect control by a thermostat shown in Figures 99 and 100.

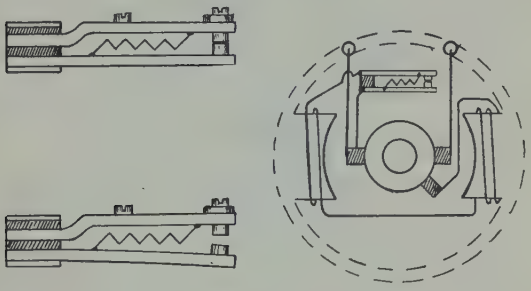


Figure 99.—Thermostat Control of Field Resistance. (Remy)

The thermostat consists of a blade formed by a strip of nickel steel attached to one of brass. Brass has the greater rate of expansion and the combination bends when heated. The blade carries one contact and the base the other, while a resistance wire is connected between the parts. While cool, the contacts are closed as at the top of Figure 98; when hot, they separate as at the bottom. The contacts are held together by the spring of the blade at normal temperatures. When the heat within the dynamo reaches approx-

imately 175° Fahrenheit, the bending of the blade causes the contacts to separate. The resistance coil is connected between the contacts. The moving blade is connected with the line leading to one of the dynamo brushes, while the stationary contact is connected with the field winding.

With the dynamo cool, the contacts are together and

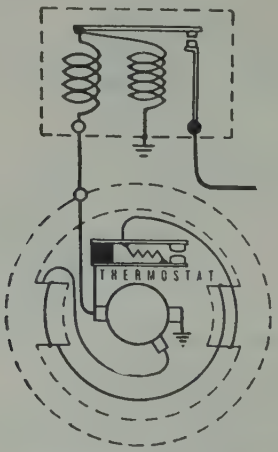


Figure 100.—Thermostat Attached to Dynamo.

the field current flows through the contacts. Heat finally causes the contacts to separate and the resistance is inserted in the field circuit so that the output of the dynamo is cut down until cooling of the parts under decrease of load or after the dynamo is at rest allows the contacts to close.

One Remy system uses four thermostats as shown in Figure 101. These open, one after another, at varying degrees of heat and cut down the dynamo output by successive steps.

OTHER CONTROL SYSTEMS

Speed Controlled Resistance.—A number of Delco motor-generators are constructed as shown in Figure 102 with the circuit connections shown in Figure 103.

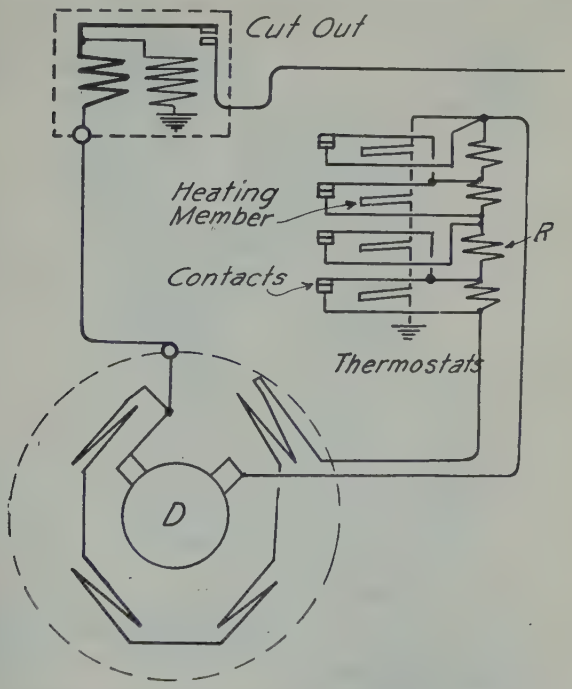


Figure 101.—Multiple Thermostat Control (Remy).

A spool of resistance wire is connected between the generator shunt field coil and ground, through which the field current returns to the generator brush. Resting on this resistance wire is one end of an arm whose other end is grounded. This arm normally rests at

the bottom of the resistance spool so that the field current flows through it to ground without the resistance being in circuit. As the generator speed increases, the arm end is raised by a centrifugal governor so that, as the arm is raised higher and higher, the field

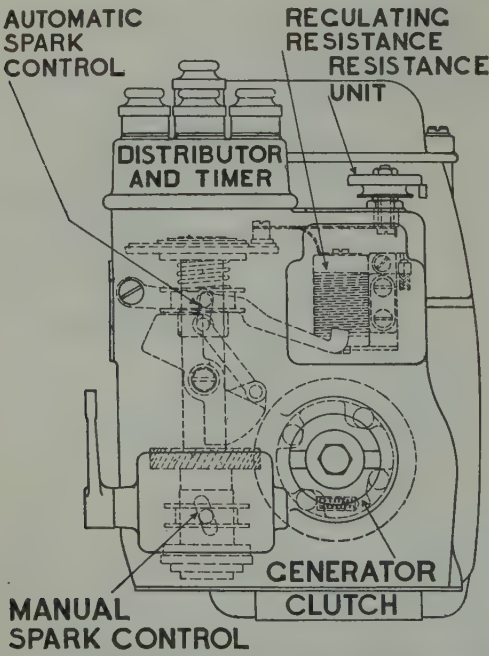


Figure 102.—Delco Centrifugal Governor Regulation.

current must flow through more and more of the resistance coil. This counteracts the effect of increasing speed and maintains the proper generator output. The generator output is changed by changing the resistance spool.

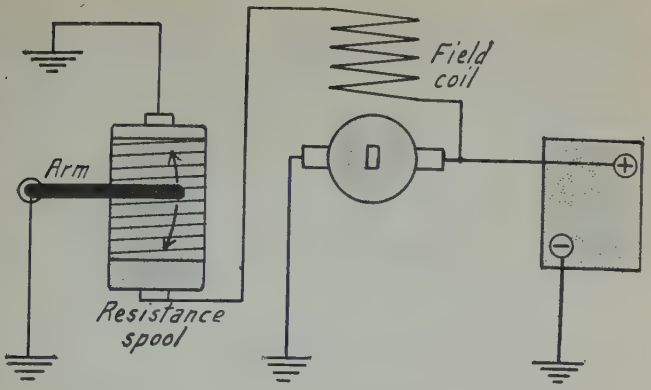


Figure 103.—Circuits of Delco Governor Regulation.

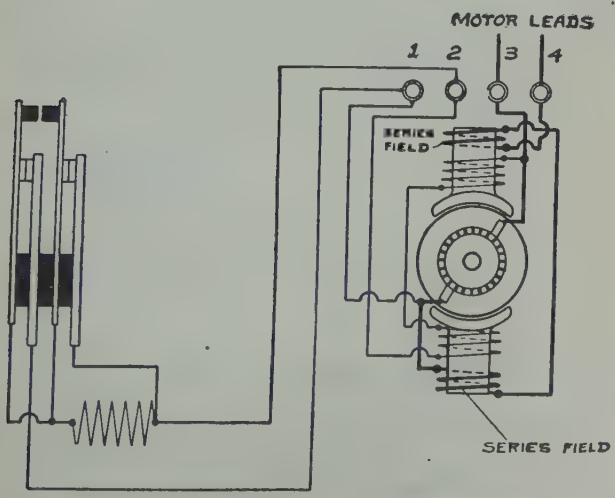


Figure 104.—Delco Ampere-hour Meter Control.

Ampere-Hour Meter Control.—The first Delco systems had an ampere-hour meter in the battery line so that the hand of the meter moved one way with battery charge and the other way with discharge. The

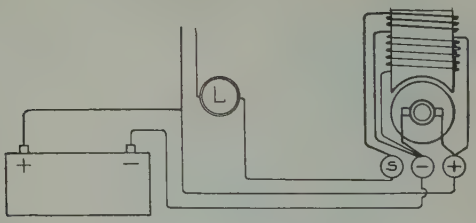


Figure 105.—Compound Winding to Lamp Load (Gray & Davis).

meter operated the contact arms shown in Figure 104 so that the field resistance was inserted when the battery became nearly charged and so that the field circuit was completely opened with a full charge.

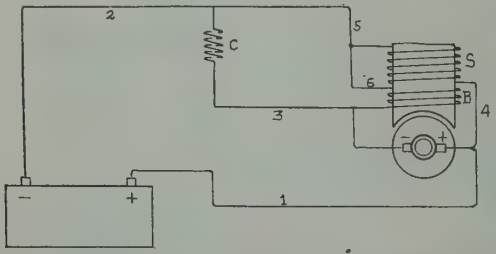


Figure 106.—Principle of Rushmore Iron Wire Regulation.

Compound Field Winding.—In Figure 105 is shown a Gray & Davis compound wound generator with the lamp current taken through the series field, terminal *S* and lamp switch *L*. The lamp current flowing

around the series field increases the field strength and generator output with the lamps turned on.

Iron Wire Control.—The principle of the Rushmore system of iron wire control is shown in Figure 106. This includes a generator with reversed series field *B* and shunt field *S*. In parallel with the reversed series field is a spool of iron wire *C*. Charging current normally flows through the low resistance iron wire in place of the reversed series field, but when this current exceeds a certain amperage it heats the iron wire, which increases its resistance greatly. This resistance forces the current through the reversed series field and controls the generator output.

CONTROL SYSTEMS IN USE

With the few exceptions that have been noted in this chapter, all of the present types of generators have third-brush regulation. The following list gives the types of control used by the various makers from their first models up to the time of third-brush adoption on newer models:

Adlake—

Constant current. Field resistance rheostat with arm moved by a balanced plunger magnet. Adjusted by changing balance weight.

Allis-Chalmers—

Constant current. Vibrating type regulator combined with cut-out.

Auto-Lite—

Permanent magnet generator; constant voltage with slipping clutch governor.

Rectangular frame generators; reversed series.

Bijur—

Constant voltage generators; vibrating type regulator carried in same case with cut-out, either on top of, or inside of, generator.

Bosch—

Constant voltage. Field resistance of carbon and mica flakes with pressure and resistance changed by plunger magnet. Spring tension adjustment.

Reversed series. On "Standard Lighting System."

Reversed series. On combined magneto-generators.

Deaco—

Current control. Magnet operated relays change field connections through resistance.

Delco—

Ampere-hour meter control of field resistance.

Constant voltage with mercury well regulator.

Reversed series on "Junior" types.

Current control with resistance spool and rheostat arm operated by centrifugal governor.

Constant current with vibrating regulator, used without a cut-out.

Detroit-Ward Leonard—

Constant current. Vibrating regulator with cut-out.

Disco—

Reversed series on double-deck machines.

Constant current. Vibrating regulator and cut-out on motor-generators.

Dyneto—

Reversed series on "Entz" motor-generators.

Reversed series on first Dyneto motor-generators.

Constant current. Vibrating regulator with cut-out.

Esterline—

Reversed series combined with load control through compound winding to lamps.

Gray & Davis—

Constant voltage. Slipping clutch governor, with load control through compound winding also.

Constant current. Vibrating regulator with cut-out, using load control on most installations.

Heinze-Springfield—

Reversed series on double-deck machine.

Jesco—

Reversed series winding controlled by a vibrating relay operated by the charging current.

Leece-Neville—

All third-brush.

North East—

Constant current. Vibrating regulator carried inside of motor-generator.

Remy—

Constant current. Vibrating regulator and cut-out.

Reversed series on M and MJ machines.

Robbins & Myers—

Constant current. Vibrating regulator and cut-out.

Rushmore—

Reversed series with iron wire control.

Simms-Huff—

Constant current. Vibrating regulator and cut-out.

Splitdorf—

Constant current. Carbon disc field resistance controlled by plunger magnet. (Apleo generators)

Voltage control. High battery voltage opens field circuit, stopping charge. (Apleo motor-generator)

Constant current. Vibrating regulator and cut-out.

Reversed series on motor-generators.

U. S. L.—

Constant current. Carbon disc field resistance controlled by magnet pressure.

Reversed series on later motor-generators.

Wagner—

All third-brush.

Ward Leonard—

Constant current. Vibrating regulator and cut-out.

Westinghouse—

Reversed series with by-pass to lamp lines.

Constant voltage. Vibrating regulator and cut-out.

REVIEW OF CHAPTER III

GENERATOR CONTROLLING DEVICES

With a **shunt wound generator,** increase of battery voltage as the battery nears full charge, sends an increased current through the field winding and increases the generator voltage and output.

The voltage and output of automobile generators are controlled by **controlling the field current.**

With **third brush control,** the number of field lines of force cut by the armature conductors connected between the third brush and opposite main brush becomes less with increase of generator speed because of the field distortion due to armature reaction. Since the shunt field winding is connected between these two brushes, the field current is decreased as the armature speed increases. This reduction of field strength finally overcomes the increase of armature voltage due to speed of rotation, and the voltage and output of the generator decrease at high speeds.

The maximum **output of third brush generators** is increased by moving the third brush in the same direction the armature rotates, and is decreased by moving this brush in the opposite direction.

With **reversed series control,** the increasing current through the series field winding counteracts the shunt field effect, and the rise of voltage and output is prevented at high speeds.

With **constant amperage control** as generally applied the charging current passes around the winding of a magnet which opens a pair of contacts against spring tension. The field current passes through these contacts, which are shunted with a high resistance. Increase of charging current opens the contacts, leaving the resistance in series with the field circuit so that the field current and generator voltage are controlled by the charging amperage through the regulator magnet.

With generally used types of **constant voltage control,** the action of inserting field resistance is similar to that of constant amperage systems, but the winding of the regulator magnet is connected in shunt with the generator brushes so

that the magnet strength is determined by the generator voltage rather than by the charging current.

With **thermostat control**, a resistance is connected between a pair of contacts through which the field current passes. Increase of temperature acts on a thermostat blade carrying one of the contacts, opening them and leaving the resistance in the field circuit to reduce the generator voltage and output.

A **relay** is an electromagnet operating current carrying contacts so that a second circuit is controlled by current through the magnet winding. Electromagnetic regulators and cut-outs use relays.

CHAPTER IV

REVERSE CURRENT CUT-OUTS

All electrical equipments that include a dynamo for charging the battery must have a switch of some kind for disconnecting these two units from each other while the engine is idle. Except with some types of motor-dynamos the switch is also opened at speeds so low that the voltage generated is not sufficient to cause charging to take place. Only two principal types are in use, one being operated automatically by an electromagnet, sometimes the regulator magnet, and the second being operated manually by the driver of the car. The switch of the second type is so connected that it will be operated with the starting switch or with the ignition switch, and thus the danger of leaving the charging circuit closed is avoided.

Electromagnetic Types.—The type of cut-out in most general use makes use of an electromagnet having one of its two windings between the dynamo brushes at all times. This magnet consists of a core of soft iron around which is wound a coil of many turns of fine wire. One end of this coil is connected electrically to one side of the dynamo and the other end of the fine wire coil is connected electrically to the other side of the dynamo. The magnet winding is, therefore, in shunt with the charging lines from the dynamo, and is called the shunt winding of the cut-out. The

proper operation of the cut-out depends on the action of a second coil of wire being added to the shunt coil. This second coil is so connected between the dynamo and the battery that all of the current passing through one side of the circuit from the dynamo during the time the cut-out contacts are closed will flow around this second coil. This winding is called the series coil of the cut-out, and the necessity for its presence will be considered after the action of the shunt winding is explained.

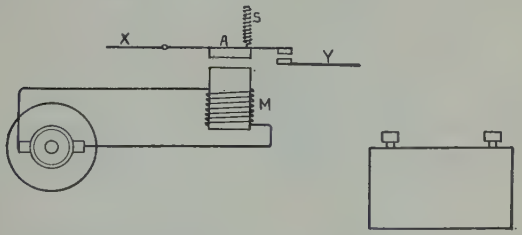


Figure 107.—Principle of the Magnetic Cut-Out.

Figure 107 illustrates the principle upon which the cut-out switch is closed. The winding of the magnet *M* is connected to the dynamo brushes as shown. The wire of which this winding is composed is so small and there is such a great length of it that the resistance through the coil is great enough to prevent more than a very slight flow of current passing through it. This avoids too great a loss of dynamo current through the cut-out itself. Mounted at some point on a hinged or spring arm above the core of the magnet is the magnet armature *A*, and when the magnetism in the cut-out magnet is great enough in strength, this armature will be attracted to the end of the magnet, overcoming the strength of the spring *S*. This will close the contacts

C, and a circuit completed through the wires *X* and *Y* will be closed by the movement of the cut-out armature.

With the dynamo idle there will be no pressure or voltage between its brushes and consequently no current will flow through the magnet winding. As soon as the dynamo starts to revolve some voltage will be generated, and this voltage will cause a flow of current through the cut-out shunt winding. The tension of the cut-out spring *S* is set at a point that holds the

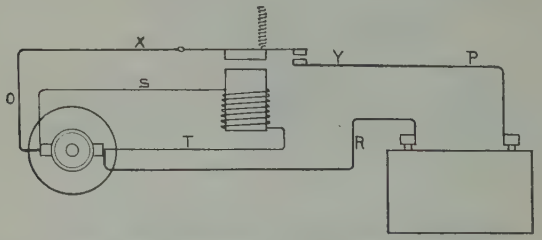


Figure 108. Elementary Magnetic Cut-Out with Battery Connections.

armature *A* away from the magnet, and consequently holds the contacts *C* apart until the dynamo voltage has risen above the voltage of the battery to which the dynamo is attached. When the dynamo is operating at a speed high enough to cause a voltage in excess of that of the battery the contacts *C* will be brought together, and the circuit through wires *X* and *Y* will be completed.

In Figure 108 the dynamo is shown connected to the battery. The wire *O* has been connected from one dynamo brush to the wire *X* and the wire *P* has been connected from the wire *Y* to one terminal of the battery. The other dynamo brush is connected to the

remaining terminal of the battery through the wire *R*. Closing of the contacts will now connect the dynamo and battery, and inasmuch as the voltage of the dynamo is above that of the battery before the contacts close, the battery will be charged by current from the dynamo.

The connections and arrangement shown in Figure 108 would be satisfactory for closing the circuit between battery and dynamo, but would not open it properly in practice. This is partly due to the fact that a much smaller current flow through the magnet is required to keep the contacts closed than is required to close them in the first place, and it is further due to the fact that after the contacts are closed the magnet winding is connected to both the dynamo and the battery so that current from either of them will hold the contacts closed.

As the dynamo speed and voltage fall, a point would soon be reached at which the dynamo would not send enough current through the magnet to keep the contacts closed against the spring tension. But when the dynamo voltage falls below that of the battery, current from the battery replaces the current of the dynamo and this battery current maintains the magnet strength to hold the contacts closed. The battery current will pass through wires *P*, *Y*, *X*, *O* and *S* to one side of the magnet winding, then through wires *T* and *R* back to the other side of the battery. A part of the current would pass through the dynamo from the end of wire *O* to the end of wire *R*, but there would still be enough going through the magnet to prevent the contacts from opening, this because of the ease with which they may be held closed.

To overcome the fault just outlined, the connec-

tions shown in Figure 109 are used, this being the method actually used. The wire *S* has been combined with the wire *O* because both of them ran from the left-hand brush to the cut-out. The connection is completed from the end of *O* through the shunt coil of the cut-out just as it was completed from the end of *S* in Figure 108. The wires *T* and *R* have been combined into the wire *R* up to the cut-out and the current that has passed through the shunt coil of the cut-out returns to the dynamo through wire *R*. The

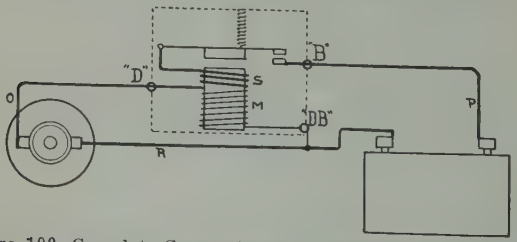


Figure 109. Complete Connections for Electromagnetic Cut-Out.

shunt coil therefore closes the contacts just as it did before.

The current from the dynamo that passes to the battery through the closed contacts now enters the cut-out at the terminal marked *D*, and flows around the additional coil *S* on the cut-out magnet, then to the contacts and from the terminal *B* through the wire *P* to the battery. The flow through the two coils on the magnet is in the same direction and the strength of the magnet is increased after the contacts close. This effect is, however, incidental. The current that has passed through the battery then returns to the dynamo through the wire *R*, passing by the cut-out terminal *DB* and flowing through *R* with the

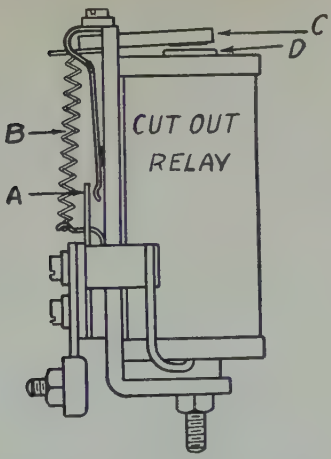


Figure 110.—A Delco Cut-Out. A—Contacts, B—Spring, C—Armature, D—Magnet Core.

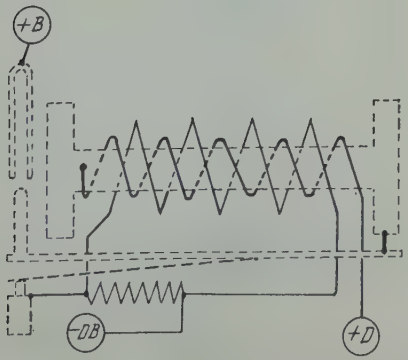


Figure 111.—Electromagnetic Cut-Out. (Splitdorf)

current that has passed through the shunt winding of the cut-out.

Now consider what happens when the dynamo voltage falls below that of the battery. Flow from the battery will take place just as soon as the dynamo voltage is low enough, but this flow must pass around the cut-out coil *S* in a direction opposite to its direction during charge. Part of this current will also pass through the lower shunt coil just as it did before, but the two coils now oppose each other because the flow of current is in different directions through them and the strength of the magnet will be completely destroyed as soon as the battery discharge through the coil *S* becomes great enough to overcome the strength of the coil *M*. At this time the contacts will be opened by the action of the spring and further discharge from the battery will be prevented. For the reason outlined, there should always be a slight discharge from the battery just before a cut-out of this type opens.

The second coil marked *S* and placed in series between dynamo and battery has another effect that is of importance. It will be realized that a cut-out having only a shunt coil would close and then reopen at approximately the same voltage. That is, if it closed at seven volts, it would open at but little below seven volts, depending on the gap. Should the car be driven at such speed that exactly seven volts, or any other voltage corresponding to the spring tension, were to be generated, the cut-out would open and close continuously with damage to the contacts from the excessive hammering and sparking. With the series coil in use this action is prevented for the following reason: The cut-out closes under the action

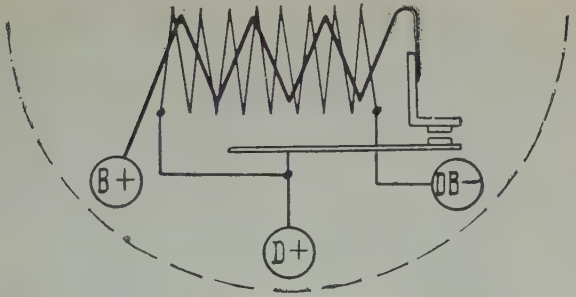


Figure 112.—Electromagnetic Cut-Out. (Auto-Lite)

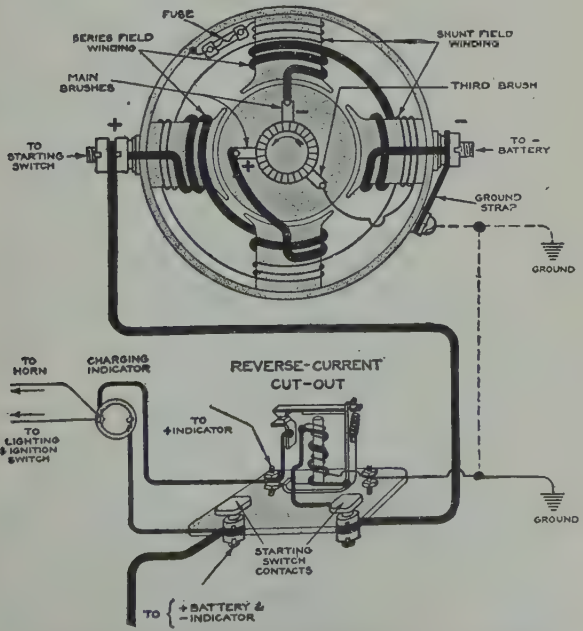


Figure 113.—Cut-Out Attached to Motor-Dynamo. (North East)

of the shunt coil acting alone, because the series coil carries no current until the contacts close. This will make the closing point come exactly when the strength of the shunt coil alone is sufficient to overcome the spring tension. After the contacts are closed the series coil adds its strength to that of the shunt and the strength of the magnet is increased. If now the dynamo voltage falls to the point at which the cut-out closed, it will not reopen because the magnet is stronger than when closing took place. The contacts will therefore stay closed until the combined strength of both coils is less than the strength of the shunt coil alone when closing took place. In practice the cut-out should stay closed until the speed of the car is about two miles per hour below the speed of closing, that is, the speed at which the contacts will reopen will be about two miles per hour less than the speed at which they close. This prevents rapid opening and closing at some critical speed of the dynamo and car.

As stated, the connections shown in Figure 56 are those generally used. Separately mounted cut-outs of this type usually have three terminals; one, *D*, leading to the dynamo only; another one, *B*, leading to the battery only; and the third one, *DB*, being attached to both dynamo and battery.

Cut-out Adjustment.—The voltage and generator speed at which a cut-out operates depend on the spring tension and on the gap between the core and armature of the magnet. With either an increased spring tension or increased armature gap the voltage and generator speed of closing will be raised. Making the spring tension less or decreasing the air gap will lower both the voltage and speed of closing. Increasing the spring tension or widening the gap

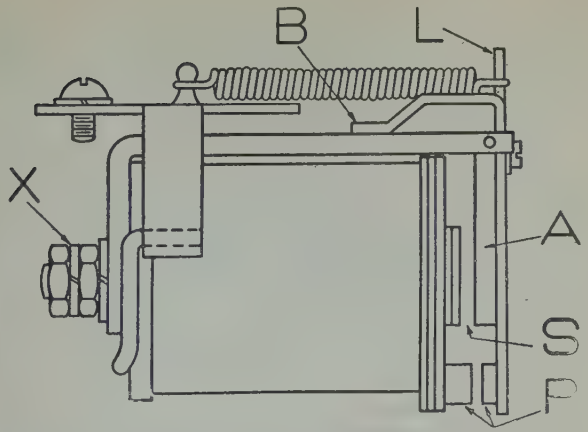


Figure 114.—Delco Cut-out Adjustment: A—Armature. B—Armature Gap Stop. L—Spring Adjustment. P—Contacts. S—Armature Gap. X—Terminal.

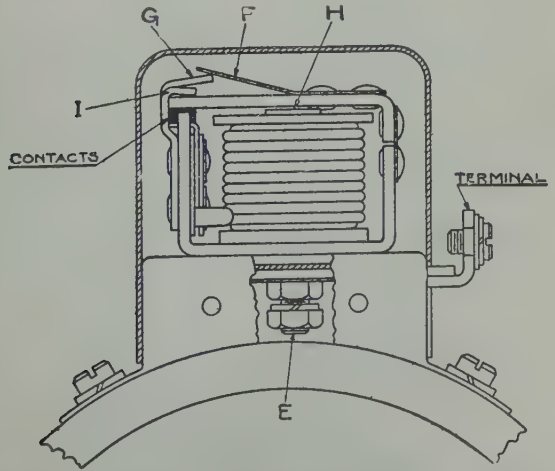


Figure 115.—Delco Cut-out Adjustment: E—Terminal. F—Spring. G—Spring Adjustment. H—Armature Gap. I—Armature Gap Stop.

will raise the dynamo and car speed of cut-out closing. Some systems provide for one method of adjustment, some for the other and some for both. In some cases no special provision has been made for either method of adjustment, but one or the other of these conditions can always be changed. In making cut-out adjustments the following points should be considered. With the cut-out open the magnetism must act across the air gap and consequently this gap affects the speed and voltage of cut-out closing. With the contacts once closed there is little or no air gap between the magnet core and its armature, and therefore the length of the gap has no effect on the time at which the cut-out will reopen. On the other hand, the spring tension is not much changed whether the cut-out be open or closed, and therefore the spring tension will affect the opening and closing about equally.

The cut-out should close just as soon as the dynamo voltage is above that of the battery. With a six-volt battery, the cut-out should close when the dynamo voltage is between 7 and 7½. With batteries of more cells and higher voltage, the dynamo voltage of closing should be in proportion. The cut-out should open when the discharge current flowing through the series coil and from the battery is between zero and two amperes. Improper operation may take place in any of the following ways:

1. Closing at a voltage below that of the battery. This will allow a discharge to take place until the dynamo runs fast enough to raise the voltage. Under such conditions the spring tension should be increased to effect a remedy.

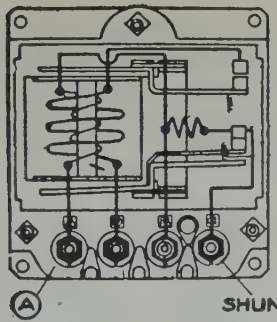


Figure 116.—Ward-Leonard Combined Cut-Out and Regulator With One Magnet.

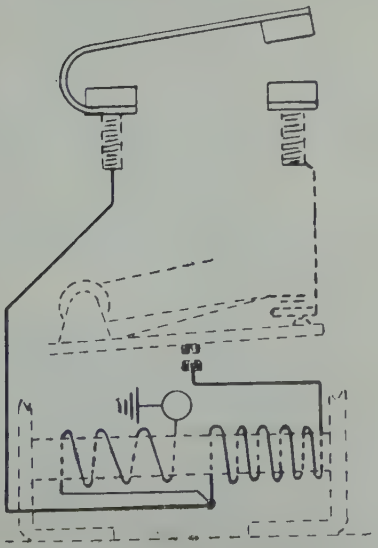


Figure 117.—Westinghouse Cut-Out Mounted in Starting Switch.

2. Closing at a voltage much higher than that of the battery. This will prevent charging at speeds as low as might be used, and the time during which the car is operating below the cut-in speed is lost as far as battery charging is concerned. The remedy is to decrease the spring tension.

3. Closing at too high voltage and remaining closed until an excessive discharge takes place. This will lessen the total time during which the battery charges and will increase the time of discharging. Lessen the air gap and increase the spring tension.

4. Closing at too high a voltage and opening before a discharge. Decrease the spring tension and air gap.

5. Closing with the dynamo voltage equal to or below that of the battery and remaining closed until an excessive discharge takes place. Allows the battery to discharge. Increase spring tension and gap.

6. Closing at too low voltage and opening before a discharge takes place. Decrease the spring tension and increase the air gap.

Cut-outs may be mounted in the dynamo, either in the brush and commutator compartment, in a housing adjacent to the brushes and commutator or underneath the arch of inverted U magnets. The cut-out will oftentimes be carried on the outside of the dynamo case. Either of these methods allow of the minimum length of wiring between dynamo and cut-out and make it necessary to run only two wires away from the dynamo with a two-wire system or one wire

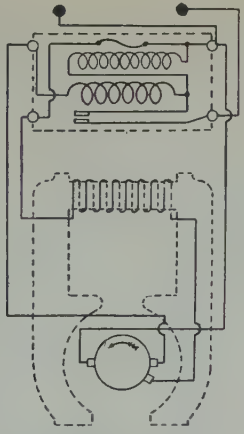


Figure 118.—Remy Cut-Out Mounted in Dynamo.

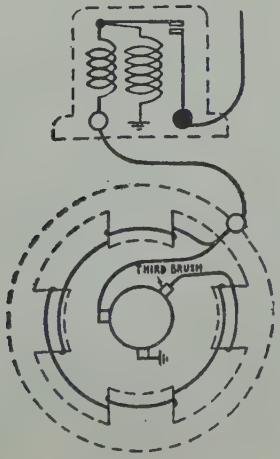


Figure 119.—Remy Separate Cut-Out.

with a one wire system. The cut-out is sometimes located on the dash or cowl, with the starting switch, or with the lighting and ignition switches.

CUT-OUT CONSTRUCTION

Auto-Lite.—Several types of cut-outs used with Auto-Lite equipment are shown in Figure 120. The two at the left hand side of the illustration have two sets of contacts, the outer pair being of carbon and the inner pair of copper. The carbon contacts are closer together than the copper, so that the carbons close first and open last. This prevents a destructive arc or flash at the copper contacts because when they open, the current is still carried through the higher resistance carbons. Any slight spark at the carbons as they open does no harm. The copper contacts are thus left clean and free to carry the greater part of the charging current.

While the arrangement of parts in each of these four cut-outs is slightly different from the others, it will be seen that the battery line always connects to the series winding, the generator line always connects to the movable contact, and the shunt winding is always between the magnet core and the dynamo-battery or ground terminal. In other types of cut-outs different connections of battery and generator lines will be seen.

Bijur.—Figure 121 shows different kinds of Bijur cut-outs. At the top is a style mounted inside the generator housing on many machines. In the center is a cut-out carried on top of rectangular frame generators and at the bottom is the type mounted on the outside of later types of round generators. The cut-outs having small coiled springs are adjusted by the

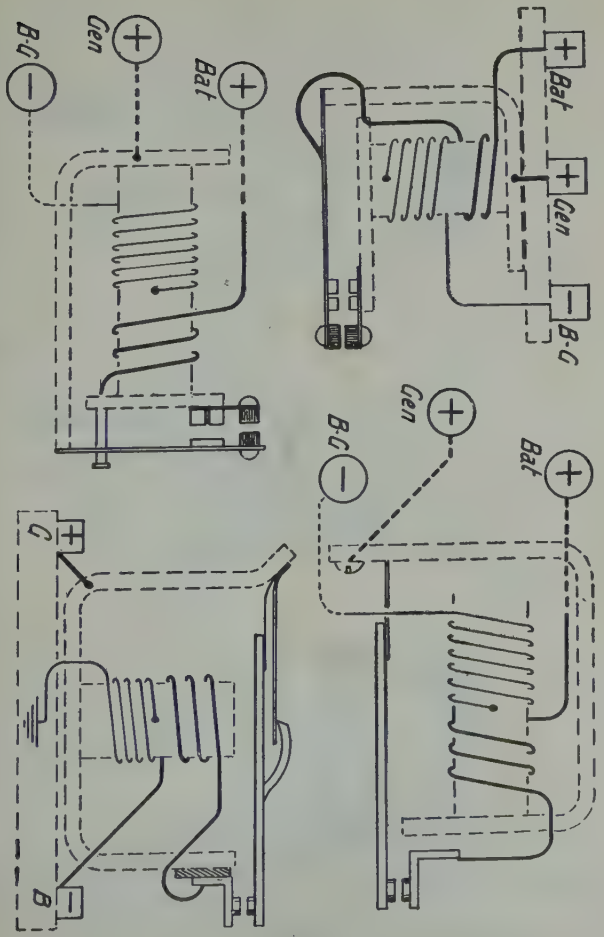


Figure 120.—Circuits Through Auto-Lite Cut-outs.

small screw and nut on one end of the spring, while those with flat springs are adjusted for spring tension

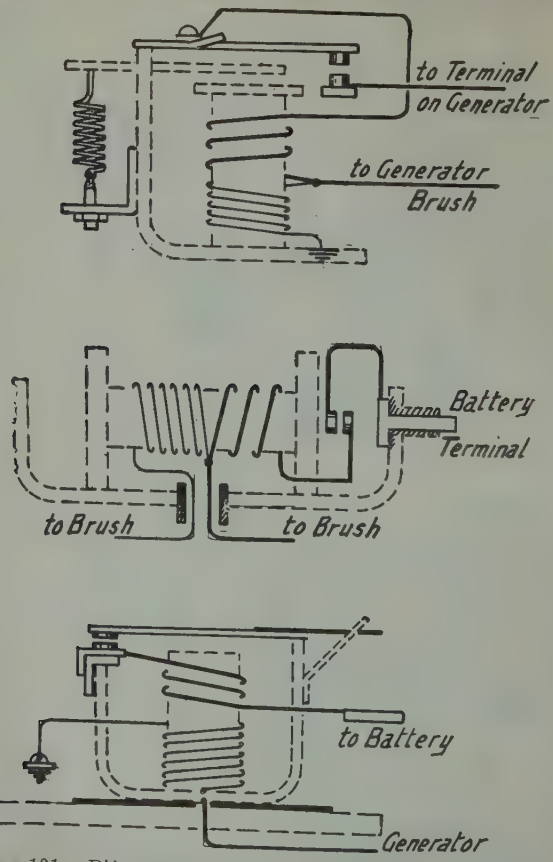


Figure 121.—Bijur Cut-outs. Top; Internally Mounted Type. Center and Bottom; Externally Mounted Types.

by bending the supporting arm. The armature gap is adjusted by bending the stop.

Gray & Davis and Bosch.—At the left hand side of Figure 122 is a cut-out used with Gray & Davis round third brush generators, and at the right is a style used with both Gray & Davis and Bosch generators. In the left hand drawing it will be seen that the battery line connects to the upper contact through the metal of the cut-out, while at the right the battery line connects to the end of the series winding.

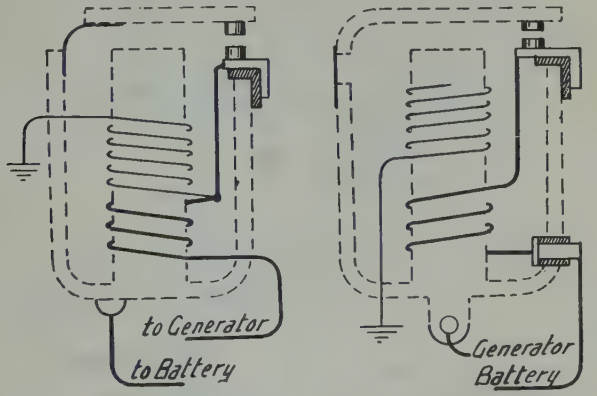


Figure 122.—Bosch and Gray & Davis Cut-outs.

Ford.—Different styles of Ford cut-outs are shown in Figure 123. At the top is shown the construction and circuits of the generally used type mounted on top of the generator. This unit has a rectangular cover. The spring tension is adjusted by bending the arm that carries the outer end of the coiled spring, while the armature gap is adjusted by bending the stop against which the upper end of the contact arm rests with the contacts open. At the bottom of this drawing are shown the circuits for two styles of cut-

outs with round covers. Some of these units were mounted on the dash in the earlier types of equipment, while others have been carried on the generator.

Remy.—A Remy cut-out having a two-pole magnet

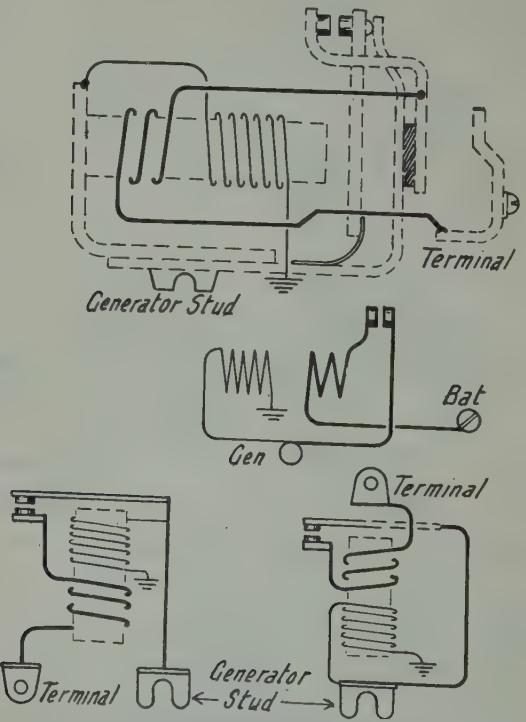


Figure 123.—Types of Ford Cut-outs.

is shown in Figure 124. This is the type of cut-out generally mounted on the outside of Remy third-brush generators that have thermostat control. The series winding shown at one pole is connected between the

generator brush and the upper contact point, with the battery line connected to the lower contact. The shunt winding is connected between the upper end of the series winding and either a ground connection on the case or the grounded brush in the generator. The shunt winding current for closing the cut-out thus flows also through the series coil before reaching the shunt. One end of the flat spring is held by a brass support which may be bent to adjust the tension. The upper contact stop may be bent to change the gap.

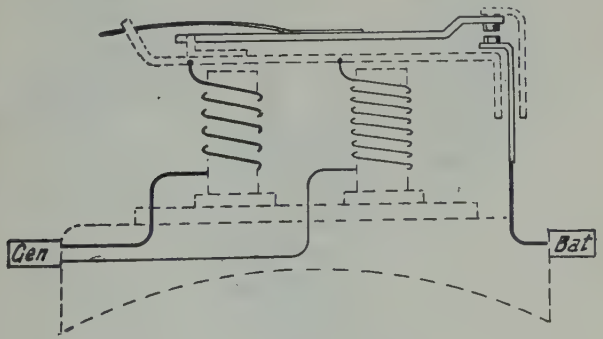


Figure 124.—Remy Cut-out.

Wagner.—Figure 125 shows three types of cut-out that have been used with Wagner systems. In two of these units it will be seen that the battery line connects to the upper contact, while in the third the battery line runs through the series winding to the lower contact, the generator being connected through the metal of the cut-out to the upper contact. All three types have but two terminals, the ground connection for the end of the shunt winding being made through the case and the mounting of the cut-out.

MANUAL OR HAND-OPERATED CUT-OUTS

All cars do not have electromagnetic cut-outs, some using a switch connected between battery and generator so that the switch is closed when the ignition is turned on and opened when the ignition is turned off. At the top of Figure 126 is shown such a Delco

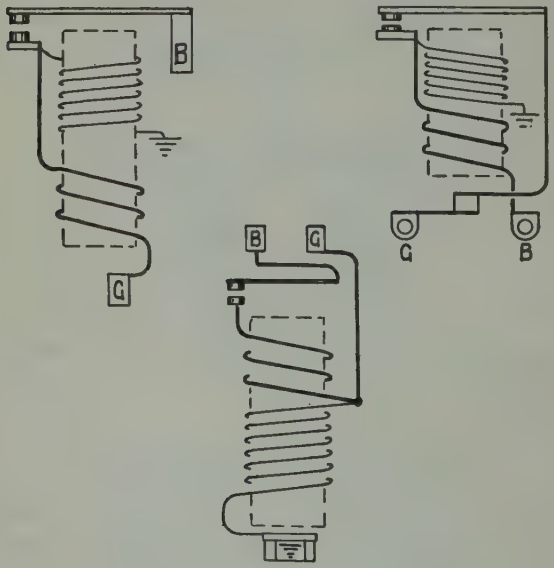


Figure 125.—Types of Wagner Cut-outs.

manual cut-out used with many of the motor-dynamo systems.

The ignition switch button has two sets of contacts. One set is connected between terminals *1* and *8* in the diagram and completes the circuit from battery to ignition coil. The other set is between terminals *1*

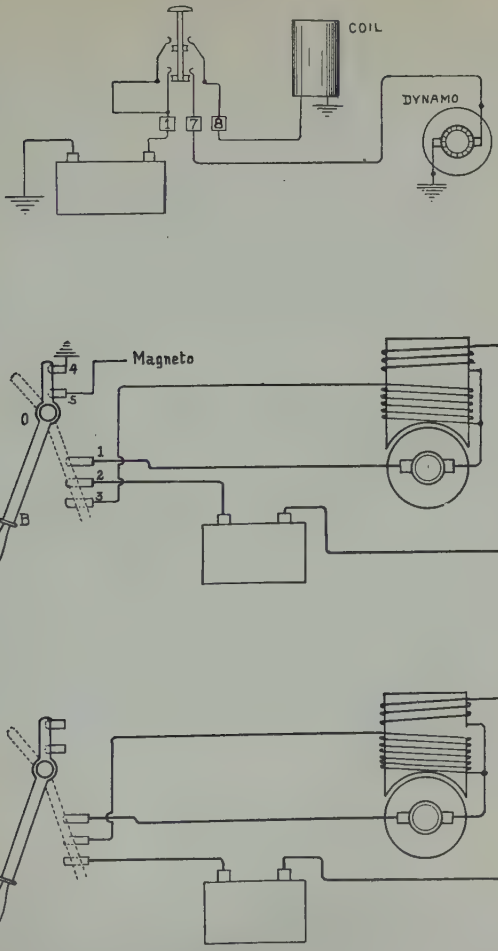


Figure 126.—Manual Cut-outs. Top; Delco Type. Center and Bottom; Dyneto Type.

and 7 and completes the charging connection between battery and dynamo.

In this Delco application, closing the ignition switch lets battery current flow through the generator circuit of the motor-dynamo and the machine operates as a motor at very low speed. The turning of the armature shaft that is thus accomplished lets the starter gear go into mesh easily so that cranking can take place when the starting switch is closed. The slight discharge through the generator circuit before the motor-dynamo runs fast enough to charge the battery is too small to make any serious discharge from the battery.

Two other motor-generator manual cut-outs are shown in Figure 126. In the center drawing, moving the handle *B* from the off position to the dotted line "On" position opens the magneto ground, allowing ignition to take place, and closes the charging circuit and shunt field circuit. The machine then cranks the engine, and after it is driven at generating speed by the engine it charges the battery. Pulling the handle a little distance back opens the shunt field circuit and stops the charge during long drives when the battery might be overcharged. A slightly different arrangement of the field and battery circuits is shown at the bottom of Figure 126.

REVIEW OF CHAPTER IV

REVERSE CURRENT CUT-OUTS

The purpose of the cut-out is to prevent discharge of battery current back through the generator when the generator is idle or running too slowly to generate voltage above that of the battery.

The **shunt coil** is connected in shunt with the generator brushes and acts to close the contacts when the generator voltage exceeds that of the battery.

The **series coil** is in series between the generator and battery. It assists in holding the contacts closed to prevent cutting in and out at some critical speed, and with a discharge of current from the battery it demagnetizes the magnet core and allows the spring to open the contacts.

A **cut-out should close** as soon as the generator voltage is above that of the battery and should open as soon as there is a slight discharge from the battery to the generator.

To make a **cut-out close quicker**, the spring tension is lessened or the armature gap reduced. To make it **close later**, the spring tension is increased or the armature gap increased.

To make a **cut-out open quicker** (with less discharge), the spring tension is increased. To make it **open later** (with more discharge), the spring tension is lessened.

When possible, the **spring tension** should be adjusted to control the opening and the **armature gap** adjusted to control the closing of the cut-out.

If a **cut-out sticks closed** when the contacts are pressed together, it may be opened by starting the engine or by disconnecting the wire to the battery or to the generator.

With a **manual cut-out** there will be a discharge of battery current between the time the ignition switch and cut-out are closed and the time at which the generator speed becomes high enough to overcome the battery voltage.

CHAPTER V

STORAGE BATTERIES

Each cell of a storage battery contains two kinds of plates, called positive and negative, made from compounds of lead and immersed in a liquid composed of sulphuric acid and water. Electro-chemical action occurs between the plates and the liquid and the result will cause generation of a flow of electricity through wires that are attached to the battery terminals. Therefore, the battery does not store, and does not contain, electricity, but is capable of generating a flow of electric current because of the action that takes place in the battery. In order to bring the elements of the battery into such condition that they will cause a flow of current, it is first necessary to send a flow of electricity through the battery. The energy of this current being sent through the battery is consumed in making certain electro-chemical changes, and when wires are connected to the battery, this same series of changes takes place in a reverse order and most of the energy absorbed from the flow of charging current is given back into the wires.

As already mentioned, the cells are made up of plates and liquid. The plates are in turn made up of a metal framework, called the "grid," Figure 128, and a paste, called the active material, with which the spaces in the grid are filled. Adjacent plates are prevented from touching each other by the use of wood insulators, Figure 129, placed between them.

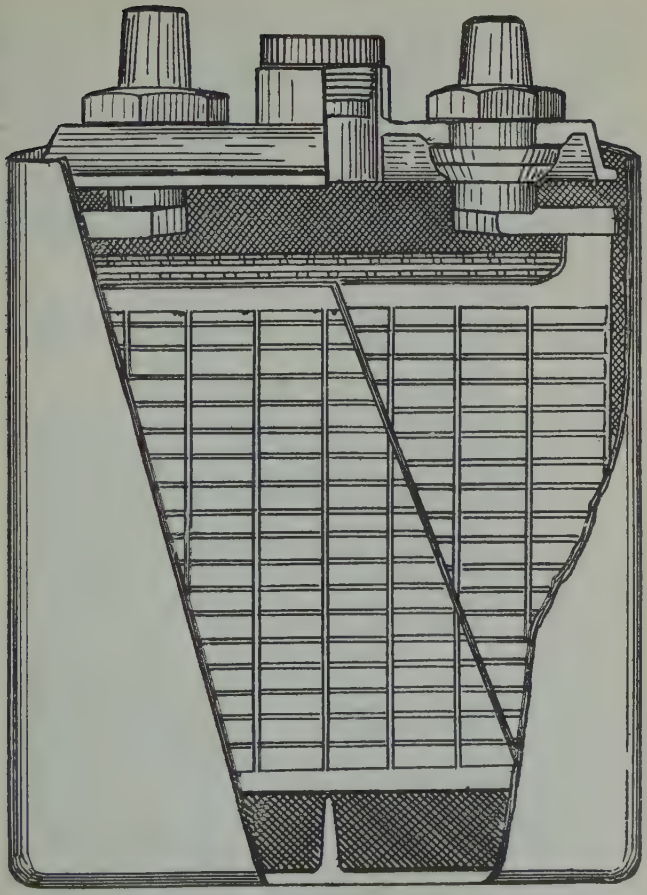


Figure 127.—Arrangement of Plates in the Storage Battery Cell.

The jar in which the plates, insulators and liquid are carried is made from some form of insulating material, often containing rubber, compounds of pitch and other materials that insulate while resisting the action of the acid in the liquid.

The grids are made from lead with which has been alloyed antimony to give the metal the necessary stiffness. Various designs and forms are in use, but they consist in a general way of vertical and horizontal

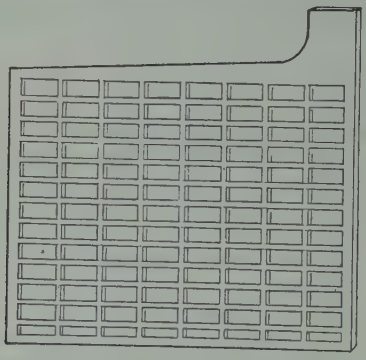


Figure 128.—Grid for Battery Plate.

bars usually spaced about three-fourths of an inch apart, measuring across the plate and about one-fourth inch apart measuring up and down. The grids, and consequently the plates, vary in thickness from about one-eighth inch up to one-quarter. The thickness of the plate has a great deal to do with the rate in amperes at which current may be drawn from the battery. Very thin plates allow the liquid in the cell to reach through them with comparative ease and a very heavy current may be taken from such a battery, while the thicker plates will only allow comparatively

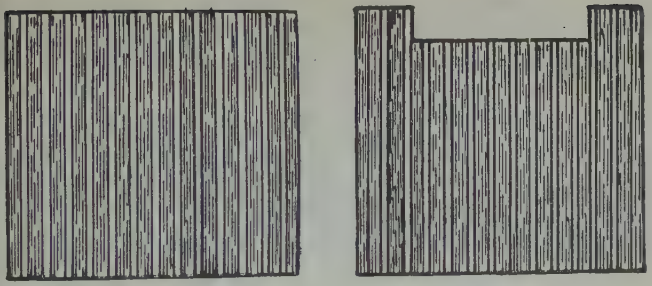


Figure 129.—Ribbed Wood Insulators.

Figure 130.—Staggering of Bars in a Grid.

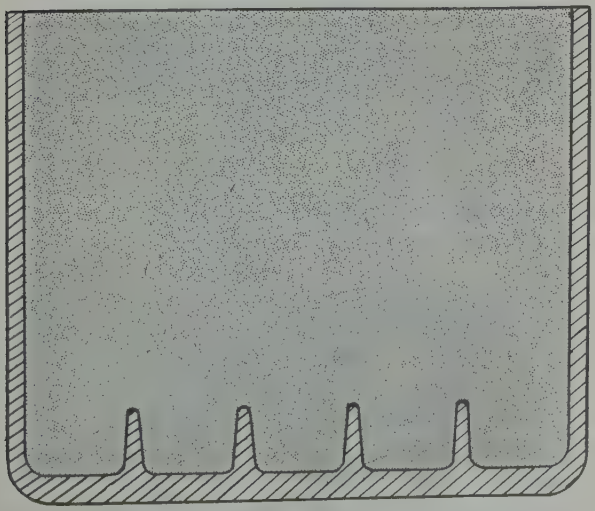


Figure 131.—Section Through Jar Showing Supports for Plates.

low amperages to be drawn through the wires. The bars of the grid are formed and spaced in such a way that they tend to hold the active material firmly in place.

After the grids have been cast they are filled with the active material by the process called "pasting," and this form of plate is called a "pasted plate." The active material is made from lead oxides, sometimes combined with other materials to give hard-

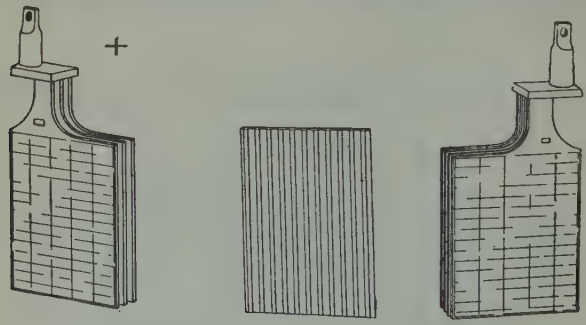


Figure 132.—Plate Groups and an Insulator.

ness and toughness and to make the plates porous so that the liquid can act on the material. The mixture is made into a paste with weak solutions of sulphuric acid and water, and the spaces between the bars of the grid are filled with this paste. After the material has set or hardened, the pasted plates are assembled with their insulators in a jar. The cell contains an uneven number of plates, Figure 132, there being one more negative than positive, and the plates are placed alternately and so that both outside plates are negative. The liquid, composed of acid and water, is then poured into the jar until it covers the plates to a

depth of one-quarter to five-eighths of an inch above their upper edges.

When the cell has been assembled all the positives are joined together and all of the negatives are similarly fastened together with connecting straps that join the lugs cast at one of the upper corners of each grid. The positive connecting strap is attached to the positive terminal of the cell or battery, while the negative strap is fastened to the negative terminal.

A flow of electric current is then sent through the

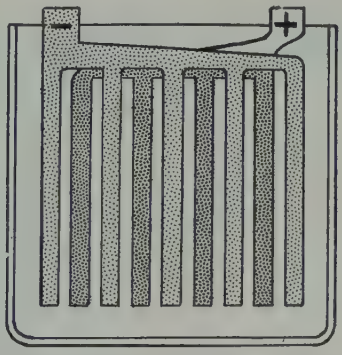


Figure 133.—Alternating Positive and Negative Plates.

cells, the positive side of the charging current being attached to the terminal that will be positive and the negative side of the source of current being connected with the negative terminal. As this current flows through the cells a change takes place in the material of the plates and the positives turn to peroxide of lead while the negatives turn to sponge lead. When the material in the grids has been completely transformed, which usually takes several reversals of current flow, the plates are said to be "formed" and the battery is charged.

There are several intermediate processes used in the manufacture of batteries, such as allowing the material to cement or harden and change its composition to some extent, but these steps need not be considered as part of the action of the battery.

The positive plates are now dark red or brownish red in color and are hard enough to resist scratching with the finger nail. The negatives are gray and are soft enough to be easily dented with any hard sub-

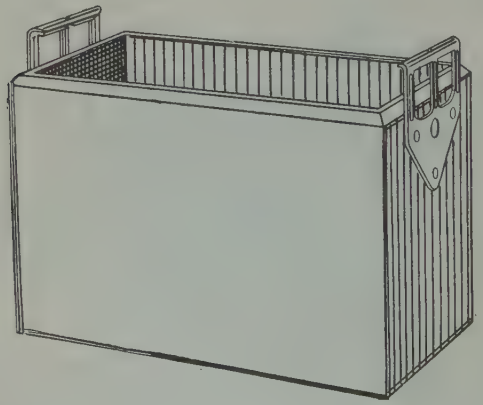


Figure 134.—A Battery Case.

stance. The material must be porous in each case, and water poured on dry positive plates should show through on the opposite side almost immediately. It is very desirable that the material in the plates be as tough as possible, so that it will not readily fall to pieces, and it should also be as lightweight as possible so that the surface exposed will be large when compared to the total weight. High grade batteries of these types will deliver a power of between nine and

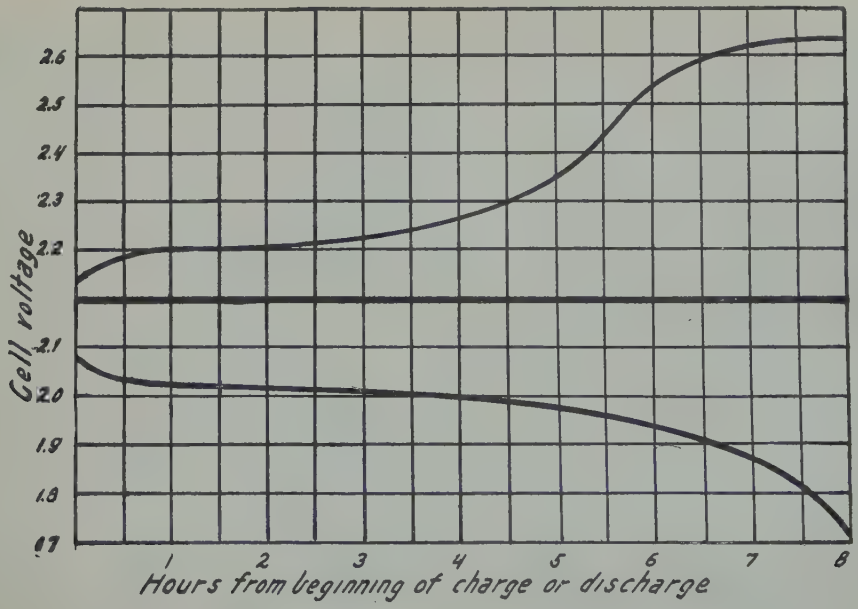


Figure 135.—Voltage Changes During Charge (top) and During Discharge (bottom).

twelve watt-hours for each pound of weight, this being the equivalent of from one and one-half to two amperes flow at six volts pressure. The battery will gradually deteriorate while in use, and when its age is between eighteen months and three years, the positive plates will have suffered a change in the form of the material so that it is an economy to replace the battery with a new one.

THE CELL

Inasmuch as all batteries must be made up of individual cells and as all the cells in one battery are exactly alike, the subject will be treated as the cell rather than the battery, and it will be understood that everything said about the cells applies to the battery as a whole.

The voltage obtained from one cell does not depend on the size or weight of the cell, as it is the same whether the battery will give a flow of only a few amperes or of several hundred amperes. The normal voltage under operating conditions is two for the cell, this voltage varying, however, with the state of charge of the battery. When the material in the plates has been completely changed to peroxide of lead and lead sponge and the cell is still charging, the cell voltage may be as high as 2.5, while with the battery discharged to a point at which no more current should be drawn, this voltage will fall to between 1.7 and 1.8 for the cell. The voltage while being charged will be higher than while being discharged, the charge voltage being between 2.1 and 2.6, while on discharge the voltage will usually run between 1.9 and 2.1. It will thus be seen that the voltage of the cell may give some indication of the condition of charge or discharge, a

voltage below 2 indicating that the cell is discharged, while a voltage of 2 or more indicates a satisfactory condition of charge. It should be understood, however, that the voltage does not form an entirely dependable indication because it is easily possible to have a high voltage with a cell that is capable of giving very little flow of current for useful work, while the voltage of a cell that is in good condition to do a great deal of work may be rather low. In making ordinary calculations it is customary to consider each cell as causing a pressure of two volts. Therefore, a

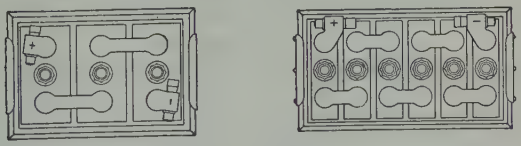


Figure 136.—Six- and Twelve-Volt Batteries with Cells in Series.

three-cell battery is called a six-volt battery, a six-cell battery is a twelve-volt battery, etc. It should be borne in mind that a six-volt battery may give a pressure of seven and one-half volts, a twelve-volt battery may give fifteen volts, when fully charged and while still on charge.

In order that the voltage of the whole battery may be equal to the number of cells multiplied by two, the individual cells are connected in series with each other. The series method, Figure 136, connects the positive of one cell to the negative of the next and the positive of the second to the negative of the third, and this connection is carried throughout the battery if it is desired to secure a voltage equal to the combined voltages of all the cells. It is possible to make other

connections that will give a lower total voltage by placing a sufficient number of cells in series to give the desired pressure and calling these cells one section of the battery. Two of these sections placed with the positive terminals of the sections together and the negatives together, Figure 137, will give a voltage only equal to that of one section, and the two parts are then connected in multiple or parallel. This method of connection is seldom used at present.

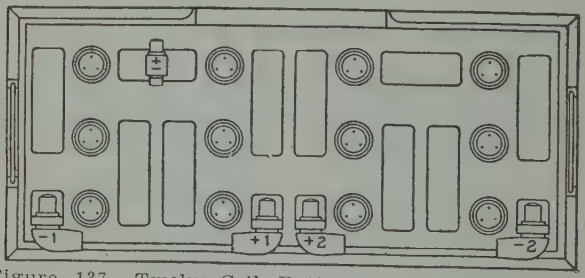


Figure 137.—Twelve-Cell Battery of Two Sections for Multiple Connection. −1 and +1, Terminals for Left-Hand Section. +2 and −2, Terminals for Right-Hand Section. Terminal Marked + and − on Left-Hand Section Is for a Neutral Wire to Provide Six-Volt Pressure.

The current that a cell will give is measured in ampere-hours or in watt-hours, generally by the former. An ampere-hour is the total quantity of current that passes in one hour if the flow is continuous at a rate of one ampere. An ampere-hour will also pass if a flow of one-half ampere is maintained for two hours and likewise one ampere-hour will pass if a flow of two amperes is continued for one-half hour or of four amperes for a quarter of an hour. The number of ampere-hours is found by multiplying the number of amperes flowing by the time in hours that the flow continues. Batteries are generally rated according to

their ampere-hour capacity, this capacity being based on discharging the battery in eight hours. A battery rated as a 120 ampere-hour battery would give a flow

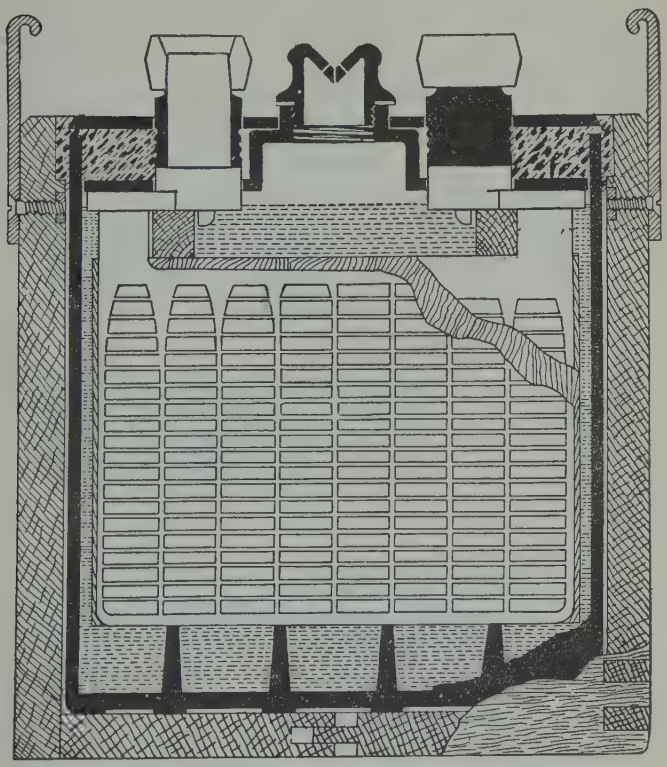


Figure 138.—Showing the Cell Cover and Sealing.

of one ampere for 120 hours, or, theoretically, a flow of 120 amperes for one hour. This latter flow could not be secured in practice, however, because of the

action that would take place in the cells under such a heavy discharge rate. The 120 ampere-hour battery should give a flow of fifteen amperes for eight hours, thus giving its normal output of 120 ampere hours. At low rates of discharge, that is, with a less number of amperes flowing, it will be possible to secure more than 120 ampere-hours, while a high rate will decrease the available number of ampere-hours.

Batteries vary in capacity according to the size and weight of the plates that are in the cells and according to the number of plates used. The greater the positive plate surface exposed to the liquid in the cells, the greater will be the ampere-hour capacity of the cells. Batteries of three cells for automobile use range in capacity between sixty ampere-hours and one hundred and eighty ampere-hours, depending on the lamp and other equipment that must be handled. Batteries of more than three cells are of less amperage in proportion to the increased voltage, although the watts that may be secured will remain the same regardless of the combination of voltage and amperage used.

The watt-hour capacity may be found from the ampere-hour capacity by multiplying this latter figure by the voltage. One watt-hour is the power secured from a flow of one ampere under a pressure of one volt (equalling one watt) for one hour. A six-volt battery of eighty ampere-hours' capacity would therefore have a capacity of 480 watt-hours.

BATTERY CHARGE AND DISCHARGE

As previously stated, a charged cell has had its positive plates changed to peroxide of lead and its negatives to sponge lead. The liquid in the cells,

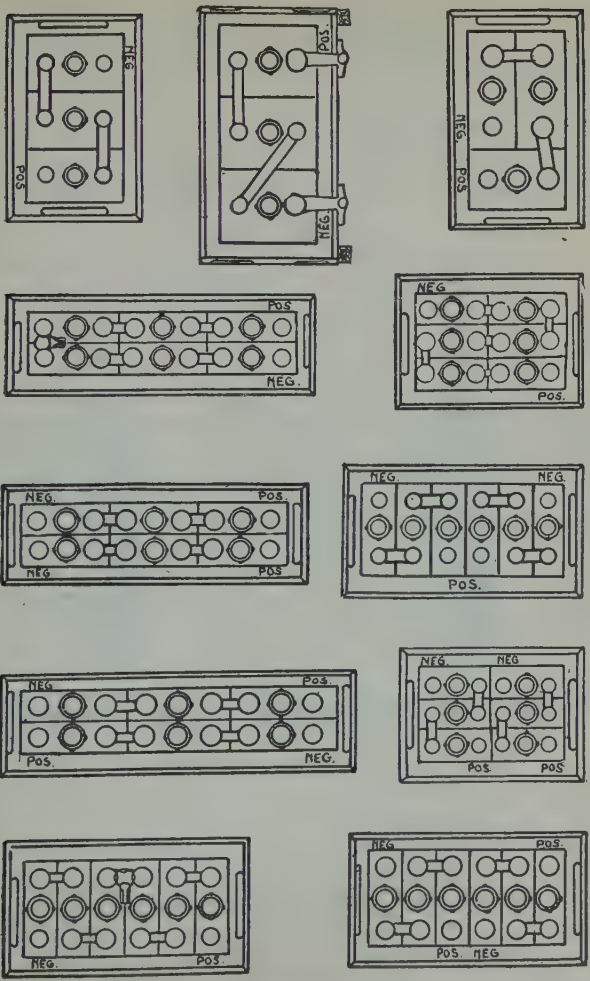


Figure 139.—Cell Arrangements of Six and Twelve Volt Batteries.

which is made from a mixture of sulphuric acid and water, is called the electrolyte. The peroxide plate, the sponge plate and the electrolyte make up the working parts of the cell.

During discharge part of the acid in the liquid combines with the lead of the plates to form sulphate of lead and the plate material gradually changes to

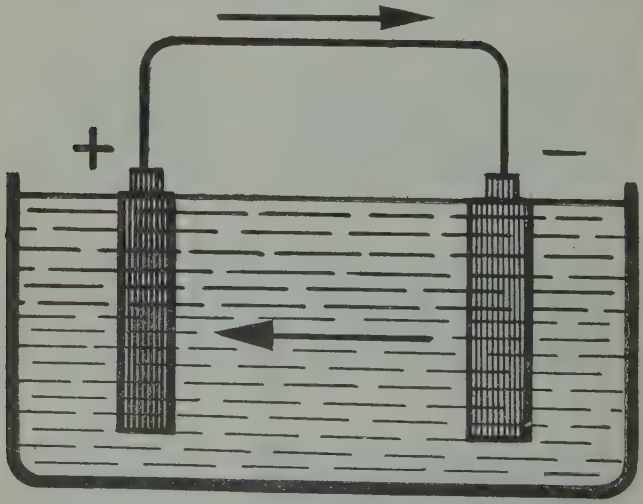


Figure 140.—Current Flow During Discharge.

sulphate. Oxygen and sulphur from the acid combine with the lead, leaving oxygen and hydrogen to form water as an increasing percentage of the electrolyte. Water is formed by this action since it is a combination of the two gases. The materials of the plates thus change slowly to sulphate of lead, while the liquid becomes more nearly pure water. When this action has penetrated a slight distance below the surfaces of

the plates, the coating of sulphate causes the change to take place at a slower rate, and the battery will then give a smaller flow in amperes and at a lower voltage. When the discharge has continued until the normal output of the battery has been secured, damage will be done by further discharge, and it will then be necessary to send a charging current through the cells in

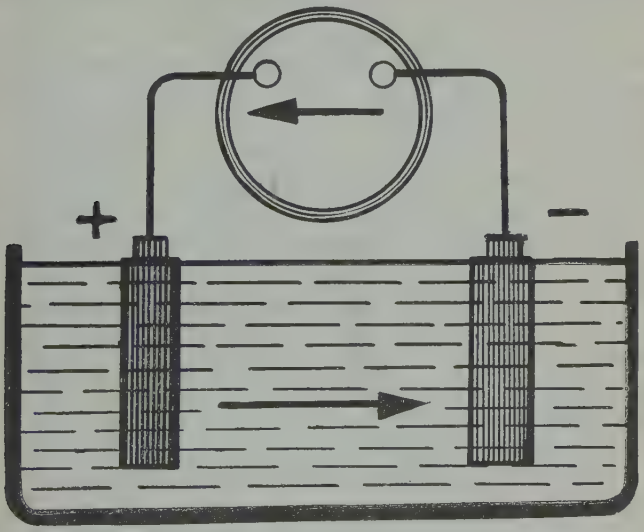


Figure 141.—Current Flow During Charge.

a direction the reverse of the flow that takes place during discharge. The water analogy can be used here, comparing the battery to a tank that has been emptied and into which a flow of water must be sent in a direction the reverse of that taken by the water that was discharged from the tank.

With the charging current flowing, the sulphate

of the plates combines with part of the hydrogen and oxygen in the liquid to form sulphuric acid. The positive plate then becomes peroxide of lead and the negative is left as sponge lead. This transformation continues until the sulphate is completely reduced, and the battery is then said to be charged. Further flow of current will not increase the charge nor the flow that may be drawn from the battery on discharge. It should be understood that the sulphate referred to here is not the injurious form that attacks the plates when they are said to be "sulphated," as a disease or trouble. Plates that are "sulphated," in the latter sense, are over-sulphated, and the deposit is then an almost pure and practically insoluble lead sulphate that prevents proper action in the cells.

The rate of flow through the battery while being charged depends on the ampere-hour capacity of the battery, and should never exceed a number of amperes equal to one-eighth of this capacity. That is, an eighty ampere-hour battery should not be charged at a rate in excess of ten amperes, or one-eighth of the total capacity if the charge is continuous.

The efficiency of a battery is greater with low rates of charge and discharge than with high rates. By efficiency is meant the proportion of current that may be withdrawn from a battery in comparison with the amount sent in on charge. The conditions of use on an automobile are favorable from an efficiency standpoint in some ways, although the conditions are hard on the battery in others. The action on the car is to give some charge while the dynamo runs and then some discharge as the lamps burn. Oftentimes the battery will be required to absorb the excess of dynamo output above the current being taken for the lamps,

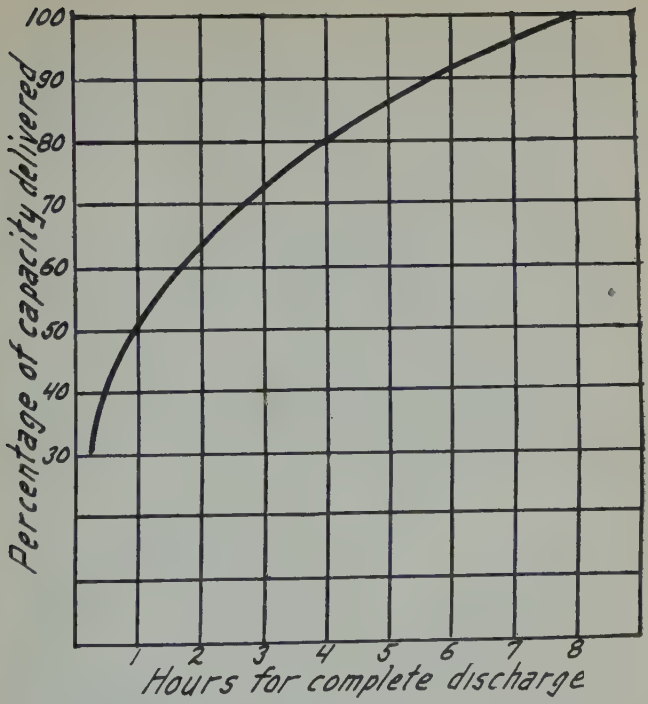


Figure 142.—Curve Showing the Percentage of the Normal Capacity of a Battery That May Be Secured When It Is Discharged to a Voltage of 1.8 per Cell in Various Lengths of Time. The Vertical Lines Indicate Hours from Beginning of Discharge and the Horizontal Lines Indicate the Percentage of the Capacity as Marked at the Left. The Intersection of the Lines on the Curve Gives the Capacity that May Be Realized.

and at other times the battery will be called upon to make up a slight deficiency between the lamp load and dynamo output. This use of the battery is called "floating" it in the lines, and it is known that the efficiencies of floating batteries are higher than for those that are completely charged and then completely discharged.

A steady discharge should not exceed in amperes one-eighth of the ampere-hour capacity of the battery, although rapid discharge is not very harmful to a battery provided it is not then allowed to stand in a discharged condition. The efficiency of the battery, if called one hundred per cent at a discharge rate of one-eighth of its capacity, drops with increase of discharge amperage until at one-sixth of the ampere-hour capacity the efficiency is about nine-tenths. At double the eight-hour rate, or one-fourth of the total capacity, the efficiency is about four-fifths, while a discharge that would empty the battery in one hour will allow less than half of the normal number of ampere-hours to be secured.

The greatest care that is necessary in allowing a battery to discharge is to see that it does not do so to such a point that the voltage becomes abnormally low. Under no conditions should discharge be continued when the voltage is 1.7 per cell, and if the current flow from the battery is carried past this point serious damage will result from over-sulphation on the plates, distortion and warping of the plates, and the formation of harmful corrosion on the metal of the grids.

The proper charging rate for the different batteries may be found from the information given on the nameplate attached to the battery case. In most

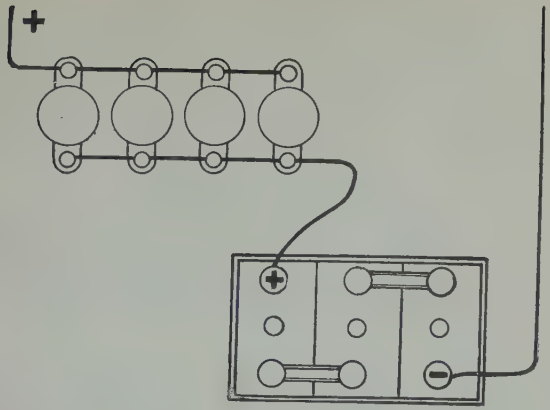


Figure 143.—Charging One Battery With Lamp Resistance.

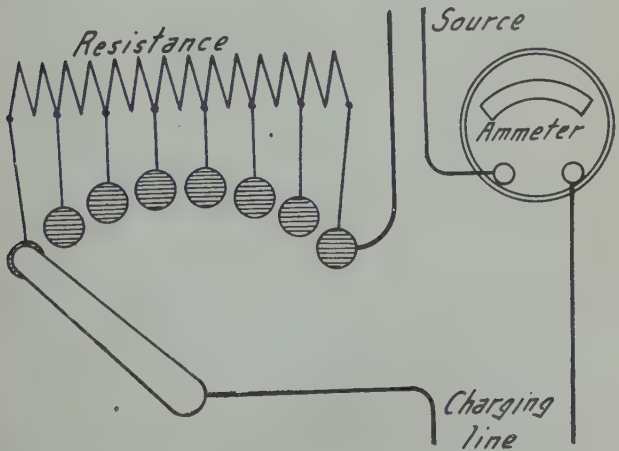


Figure 144.—Control of Charging Current With Rheostat.

cases two different rates will be given, one marked "start," and the other "finish," or "24-hour." The starting rate is the greatest that the battery will stand, and should be as great as the highest rate of charge that the dynamo can send through the battery. The finish rate is used when the battery is charged from an outside source of current other than the car's dynamo. The high rate is between one-sixth and one-tenth of the capacity in ampere-hours, generally about one-eighth. The finish rate is approximately one-fourth to one-half of the high rate, generally about one-third.

When it is necessary to charge a battery from an outside source, it must be remembered that the positive side of the charging current must be attached to the positive terminal of the battery and the negative of the charging current to the negative of the battery. The polarity of any wires may be determined by immersing their ends in water to which has been added a small amount of acid or salt. The wire that comes from the negative side of the source will bubble most.

The charging current must always be direct current. Alternating current connected directly to the battery without the use of a rectifier will not only fail to charge the battery, but will do positive damage. Direct current is abbreviated, D. C., and alternating current, A. C. It will be necessary to ascertain which kind of current is supplied by the charging circuit to be used, and if it is alternating, a rectifier must be inserted between source of current and the battery to be charged.

With a supply of direct current at hand, the battery may be charged by inserting such a resistance in the line as will allow the proper amperage to flow through

the cells. The high voltages found on lighting and power circuits in buildings would send a damaging flow through the cells, and it will always be necessary to use incandescent lamps or other forms of resistance with such current and voltage. (See Figure 145.)

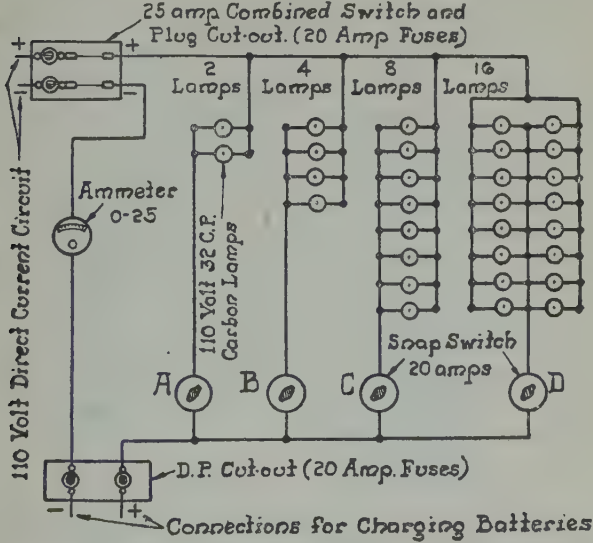


Figure 145.—Battery Charging with Lamps for Resistance.

A sufficient number of incandescent lamps may be lighted at one time to allow the amperage to flow at the rate marked "finish," or "24-hour." If the lamps to be used are marked on their bulbs with the number of watts required, as is usually the case, enough lamps must be lighted to give a total number of watts when added together that will allow the proper amperage to flow. The amperage desired should be multiplied

by the voltage of the charging line, this giving the number of watts required. Enough lamps must then be used to make up this number of watts. Thus, if the battery requires three amperes charge and the charging current is 110 volts, three times this voltage gives 330 watts as the result. Seven 50-watt bulbs will make 350 watts, which will be just about right. If the lamp bulbs are marked in candlepower, their wattage may be found by multiplying the candlepower by three for carbon filament bulbs, or considering a 16 c.p. bulb as a 50-watt bulb and a 32 c.p. bulb as a 100-watt bulb, etc. If tungsten lamps must be used, the candlepower and wattage are equal, that is, a fifty-candlepower bulb is a fifty-watt bulb.

A battery should have each cell filled with pure water until the level is above the tops of the plates before any charging is done; this applies whether the battery is charged on the car or from an outside source. When giving an outside charge it is desirable that the current should flow without interruption until the charge is complete.

ELECTROLYTE AND TESTING

From the explanation given of the action that takes place during charge and discharge, it will be seen that the proportion of acid in the electrolyte will give an indication of the condition of the battery, that is, whether it is properly charged or nearly discharged. The acid is much heavier than water, and as the proportion of acid in the liquid becomes greater, the weight of the electrolyte becomes greater. Therefore, the heavier the electrolyte, the more nearly charged the battery is known to be.

To find the condition of the battery by testing the

liquid, a hydrometer is used. The hydrometer (Figure 146) is a glass tube having a hollow bulb and a weight at one end and a thin tube with a numbered scale at the other end. When this instrument is

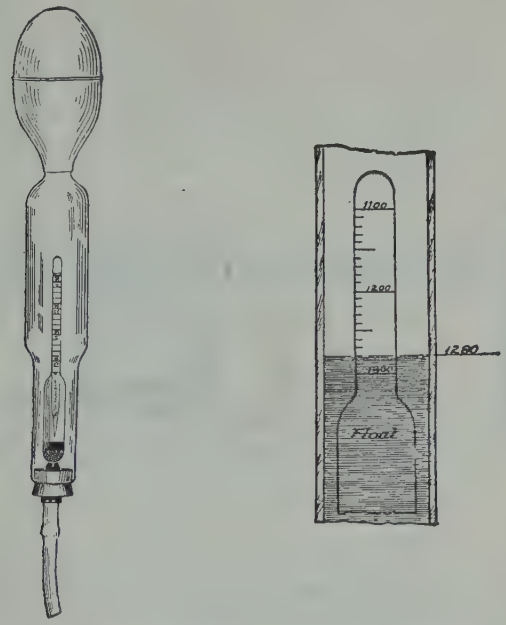


Figure 146.—Hydrometer Syringe and Hydrometer.

allowed to float in the liquid from the battery cells, the point on the scale to which it sinks indicates the weight of the liquid, because, of course, the hydrometer will not sink so deep into the heavy liquid with a large proportion of acid as it will into the liquid when almost all water. The scale is graduated accord-

ing to the weight of liquids compared with the weight of water. The stem of the hydrometer is numbered from 1.100 near the top to 1.300 near the bottom. If the liquid contains a great deal of acid it is heavy and the hydrometer sinks only to around the 1.300 mark, but with mostly water the liquid is light and the hydrometer goes down around the 1.100 mark. The point on the scale at which the hydrometer rests in the liquid is the specific gravity of the electrolyte.

The hydrometer is carried in a hydrometer syringe.

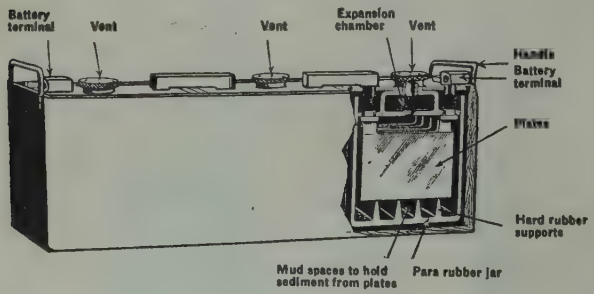


Figure 147.—Construction of Complete Battery.

With the cell vent plug removed, liquid is drawn up into the syringe, the specific gravity is noted and the liquid returned to the same cell.

Gravity between 1.250 and 1.310 indicates full charge, between 1.200 and 1.250 it indicates between half and full charge, between 1.150 and 1.200 it indicates less than a half charge, and below 1.150 it shows complete discharge, after which no more current should be used. The gravity is often spoken of in "points," the difference between 1.200 and 1.225 being 25 points.

Battery Care.—Keep battery terminals and connections coated with vaseline or grease to prevent verdigris. Wipe off any spilled electrolyte with a cloth wet with ammonia water to kill the acid. Unless to adjust the gravity after a charge, do not add acid or electrolyte, but use only distilled water to keep the electrolyte level up. Add water every week or ten days in warm weather and every two weeks in cold weather.

Do not test the gravity after filling cells with water until the liquid has been mixed by charging the battery or running the car. The gravity should test within 25 points of the same in all cells of a battery in good order at the end of a full charge. Gravity in one cell much below the others indicates trouble. If this cell takes more water than others it shows a cracked jar, otherwise an internal short circuit or similar trouble.

A complete explanation and description of automobile batteries and battery work in charging, care, and repair shop practice is given in *Automobile Battery Care and Repair,* another volume of this series.

REVIEW OF CHAPTER V

STORAGE BATTERIES

The **plate grids** are made of lead-antimony alloy; the **active material** for the negative plate is sponge lead and for the positive is peroxide of lead.

The **electrolyte** is made of pure sulphuric acid diluted with pure water.

All the plates of one polarity are fastened together with plate straps to form a **group**; the positive and negative groups are placed together with separators or insulators between alternate plates to make the **element**; and the

element and electrolyte in their jar with its cover and terminals form the **cell.**

Positive plates are dark brown in color, **negative plates** are gray.

In every cell the two **outside plates** are both **negative.**

The **cell voltage** during charge rises from 2.2 to 2.5 or 2.6. During discharge the cell voltage falls from 2.1 to 1.8 or 1.7.

The **normal voltage** of a battery is equal to the number of cells multiplied by two.

During charge the lead sulphate is reduced to peroxide of lead in the positive plates and to sponge lead in the negatives, with the electrolyte becoming stronger in acid. **On discharge,** these actions are reversed.

A battery will give a **greater discharge** in ampere-hours at **low rates** of discharge than at high rates.

Direct current or pulsating current may be used for **battery charging,** alternating current cannot be used.

A **specific gravity reading** of 1.250 to 1.300 indicates full charge; 1.200 to 1.250 indicates half charge; 1.150 to 1.200 less than half charge; and below 1.150 indicates complete discharge.

The **terminals and connections** should be kept clean and greased.

The **level of the electrolyte** should be kept from ¼ to ½ inch above the plate tops by adding distilled water to make up for evaporation.

A **battery is floating** on the lines when it is connected so that it is charged when the line voltage is above that of the battery and so that it discharges when the line voltage is below that of the battery. Automobile batteries are floating between the generator and the lamps or other load.

CHAPTER VI

LAMPS AND WIRING

One of the principal purposes of the whole electrical system is to furnish light, and the subject of lamps and their connections is an important one. The lighting parts that are most directly concerned are the bulbs and reflectors in the lamps, the wiring with its insulation and supports, the switches for turning the lamps on and off, and, in some cases, the protective devices, such as fuses and circuit breakers.

THE LAMPS

Bulbs.—A bulb is composed of a filament enclosed in a glass housing from which the air has been almost completely exhausted, and this glass part is carried on the metal base (Figure 148). Two kinds of filament are in use, tungsten and carbon, and two kinds of bulbs, one in which the exhausted air is not replaced, and another in which the air is replaced with nitrogen gas. The first kind of bulb is known as the vacuum type, the second is called a nitrogen bulb.

Tungsten filaments should be used exclusively because of their greater efficiency as compared with carbon. Depending on the candlepower, the tungsten filament will require from 0.95 watts for each candlepower up to 1.25, while the carbon bulb will take on an average of 2.5 watts for each candlepower of light. It is, therefore, poor economy to use carbon filament

bulbs for any purpose. In making lamp calculations the following data may be used:

Bulbs up to 4 c.p....1.2 watts per candlepower
6 c.p. to 10 c.p.....1.0 watts per candlepower
12 c.p. and above.... .95 watts per candlepower

Bulbs operating at their normal voltage will require an amperage sufficient to allow the specified consump-

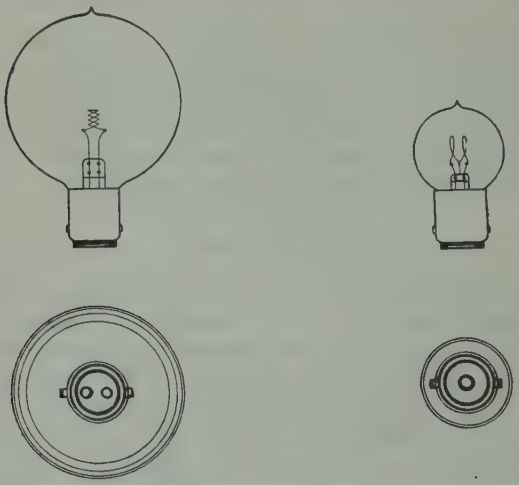


Figure 148. Double-Contact and Single-Contact Lamp Bases.

tion in watts. This will cause the bulb to give its full candlepower, and its useful life may be expected to reach from 200 to 300 hours of burning. If the voltage is less than normal, the bulb will not require its rated flow in amperes, and under these conditions the candlepower will be lower and the life longer.

Bulbs in common use range in voltage from 3 or 3½ up to 21, depending on the number of cells in

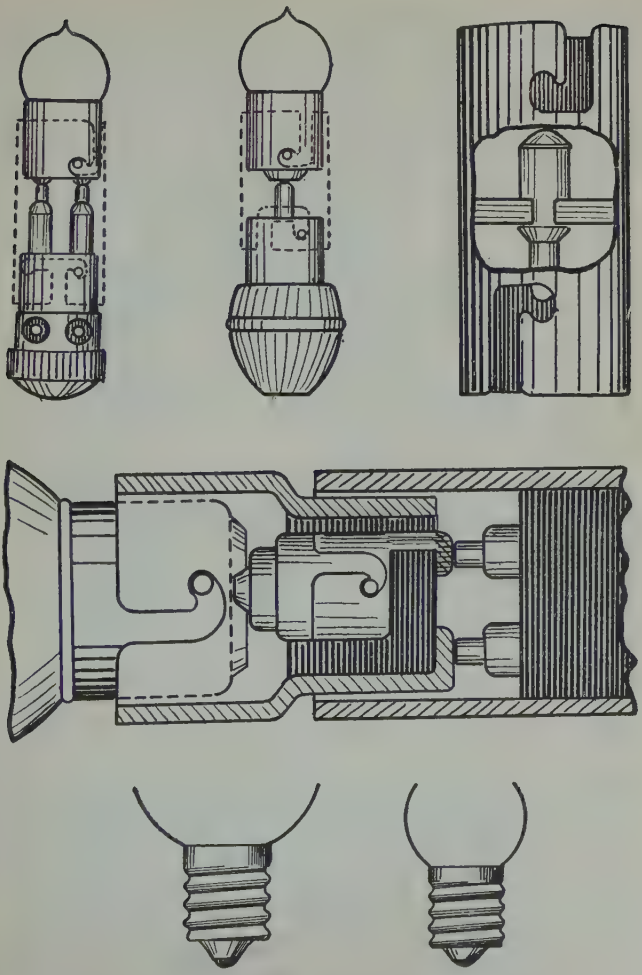


Figure 149.—Lamp Socket and Base Construction.

the car's storage battery with which they are to be used. For a three cell 6-volt battery, bulbs rated at 6-8 volts are used; for a six cell 12-volt battery the bulbs are rated at 12-16 volts. When used in a series circuit, 3½-volt bulbs are used with a 6-volt battery system.

Bulb Bases and Sockets.—Except for a few interior

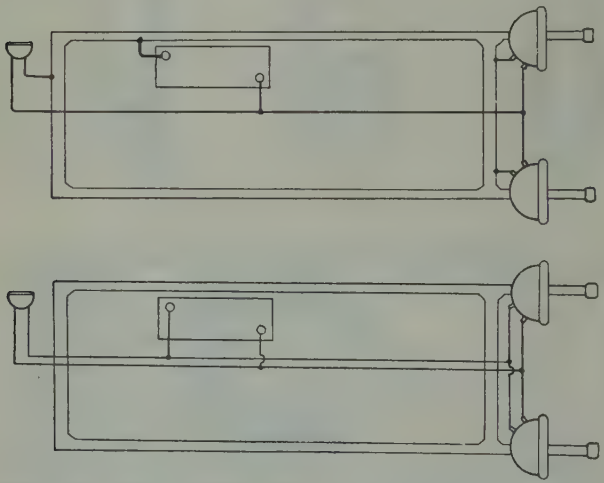


Figure 150.—Single-Wire (top) and Two-Wire (bottom) Connections.

lamps all bulb bases and sockets are of the bayonet type at the top of Figure 149. The bulb base carries two small projecting pins which slide down into slots on the side of the socket until they can be turned to catch in notches at the bottom of the slots. The contacts in the socket against which the bulb contacts press are made of strips of spring bronze or of spring plungers so that the spring action holds the bulb base

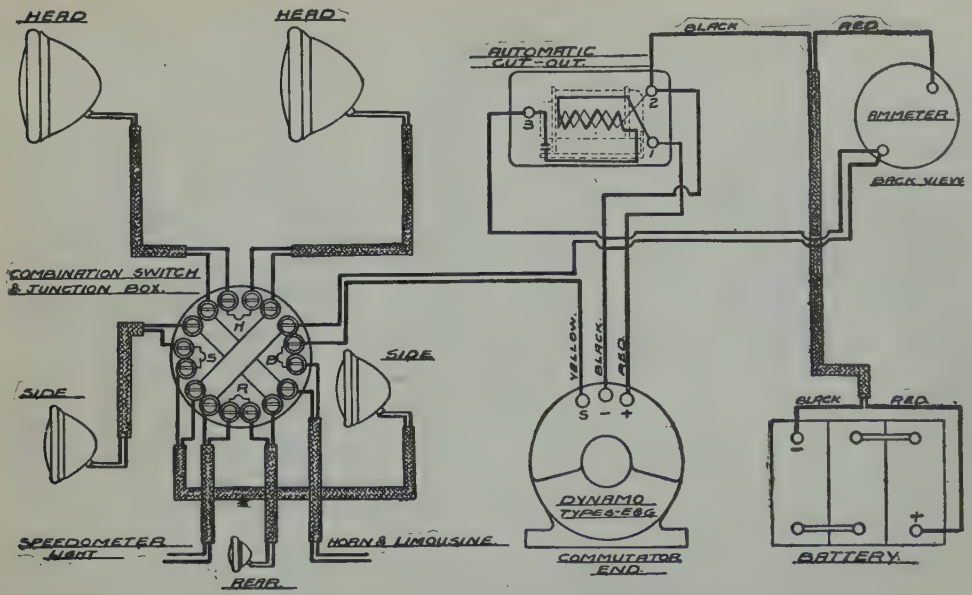


Figure 151.—Gray & Davis Two-Wire System.

securely in the socket until it is pressed down and turned to loosen it. As shown in Figure 149, some of these bulbs and sockets have two contacts or plungers, then being used for wiring in which both sides of the circuit are insulated. They are called double contact bulbs and bases. The other type has but one contact in the socket and one on the bulb base, this being used where there is a return circuit through the metal parts. It is called the single contact type.

Two sizes of screw bases are shown at the bottom of Figure 149. These are called candelabra for the larger and miniature for the smaller size.

WIRING

There are three methods of car wiring; the single-wire, one-wire or ground return system being by far the most common; while the older two-wire and three-wire systems are seldom found in new installations.

The principle of the single wire system is shown at the top of Figure 150. One side of the battery and all other electrical units are connected with the metal of the car's framework to form either the positive side or negative side of the circuit. The other sides of all units are then connected with single wire conductors. The metal framework, called ground, thus forms one side of all circuits.

The principle of the two-wire system is shown at the bottom of Figure 150. Here no units are grounded on the frame and both sides of all circuits are carried through insulated conductors. Even with a single wire system, some of the parts may require two wires because of not being mounted directly on metal parts of the car. With one-wire systems either the positive or negative sides may be grounded, some equipments

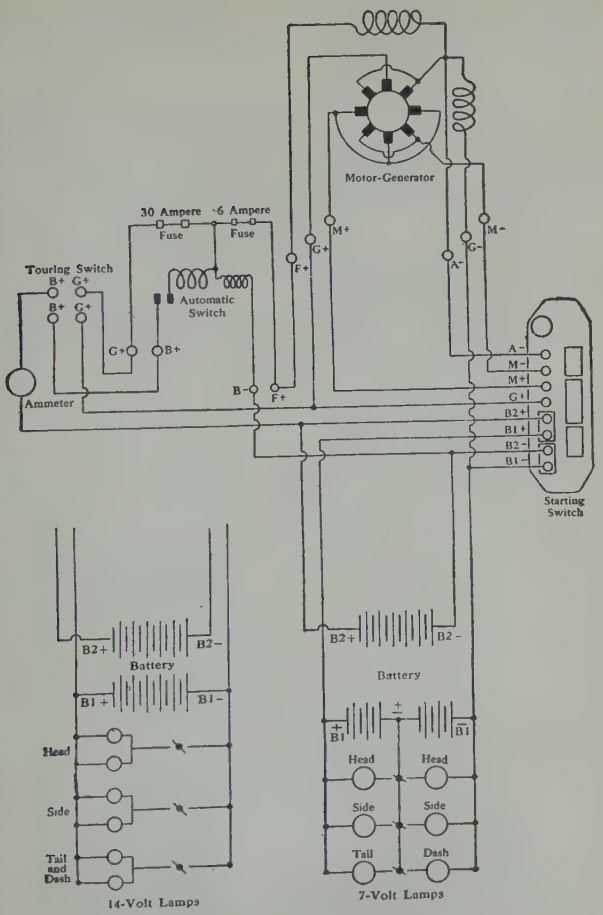


Figure 152.—Three Wire System. (U. S. L.)

using a positive ground while others ground the negative side of the circuits. A complete two-wire system is shown in Figure 151.

A three-wire system, which, however, is now obsolete, is shown in Figure 152. Half of the lamps are connected to one half of the two part battery, while the other lamps are connected to the other half of the battery. Any unbalance between the load of lamps on one side and the load on the other side of the battery is equalized by the difference in current passing through the center wire, called the neutral wire.

The symbols that are generally used to represent various electrical units and wire connections in making diagrams for this work are shown with their names in Figure 153.

Wires.—The characteristics and dimensions of conductors for this work are shown in the Copper Wire Table. Wires are specified according to American Wire Gauge size, numbered from 0000 down to 40, as shown. The area is given in circular mils, one circular mil being the area of a circle 1/1000 of an inch in diameter. The resistance is given for cool wires (68° F. or 20° C.) and for hot wires (176° F. or 80° C.). Sizes from number 0000 down to number 1 are used for starting circuits; numbers 10, 12 and 14 are used for charging circuits; and numbers 14 and 16 for lighting and accessory circuits. Smaller sizes are used for the windings of electrical units such as cut-outs, regulators, fields, ignition coils, etc.

The insulation of the wire gives protection against leakage of the current and also against mechanical injury. Electrical protection is cared for by compounds of rubber that surround the conductor with a coating sufficiently thick to resist the voltage in

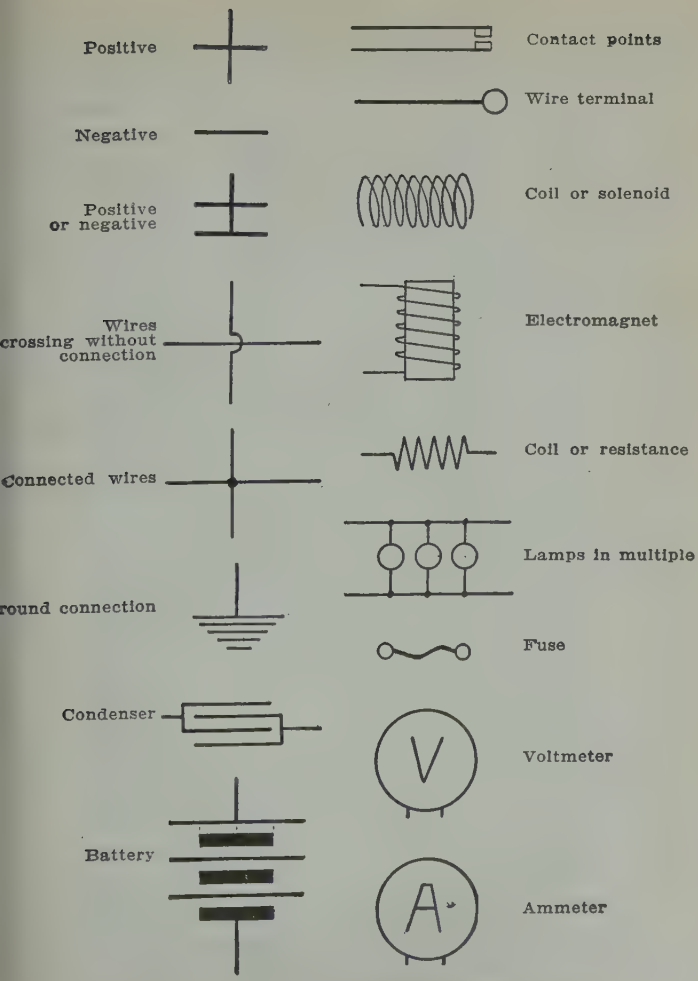


Figure 153.—Symbols Used in Wiring Diagrams.

use plus a liberal margin for safety. Various means are used to give mechanical protection, the commonest being a covering of fabric woven or braided over the electrical insulation of the wire. In many installations the mechanical protection is given by covering the wire with a flexible housing of braided brass or very thin steel. This type is called armored cable, and gives excellent results in use.

The wiring should be firmly fastened to the parts of the car near which it runs, and these fastenings should be made with screwed joints of some form. The wires should never be fastened in such a way that the covering will come into contact with corners or sharp edges of metal, because the final result will be breakage or short circuits. In case it is necessary to run the wiring into positions where it will be exposed to the possible action of grease, oil or water, it should have a weatherproof coating of some form. If armored cable is not used it is general practice to use metal tubing of flexible construction, or else to use conduit. Should neither of these protecting coverings be supplied, the needed protection may be given by covering the exposed portion of the wiring with ordinary circular loom, such as is used in stationary electrical construction.

No wire should be used that is not designed for starting, lighting or ignition work. This means that the conductor must be composed of a cable made up from a large number of fine wire strands and known as flexible or stranded cable. The insulation must be designed for this class of work, and under no conditions is it permissible to use substitutes like flexible lamp cord, such as is found in house wiring.

All wire ends should be fitted with metal terminals

COPPER WIRE TABLE

Gauge Size	Diameter Inches	Area Circ. Mils	Feet per Pound	Ohms per Foot Cool	Ohms per Foot Hot	Carrying Capacity Amperes
0000	0.4600	211,600	1.56	.0000489	.0000606	340
000	0.4096	167,800	1.97	.0000617	.0000764	280
00	0.3648	133,100	2.48	.0000778	.0000963	235
0	0.3249	105,500	3.13	.0000981	.0001215	200
1	0.2893	83,690	3.94	.0001237	.0001532	170
2	0.2576	66,370	4.98	.0001560	.0001932	140
3	0.2294	52,630	6.28	.0001976	.0002435	110
4	0.2043	41,740	7.91	.0002480	.0003071	90
5	0.1819	33,100	9.99	.0003128	.0003872	80
6	0.1620	26,250	12.58	.0003944	.0004883	70
7	0.1443	20,820	15.87	.0004973	.0006158	60
8	0.1285	16,510	20.01	.0006271	.0007765	50
9	0.1144	13,090	25.23	.000791	.000979	45
10	0.1019	10,380	31.82	.000997	.001235	35
12	0.0808	6,530	50.59	.001586	.001963	30
14	0.0641	4,107	80.44	.002521	.003122	25
16	0.0501	2,583	127.9	.00401	.00496	15
18	0.0403	1,624	203.4	.00637	.00789	10
20	0.0319	1,022	323.4	.01014	.01255	5
22	0.0253	642	514.2	.01612	.01996	2
24	0.0201	404	817.6	.02563	.02863	
26	0.0159	254	1,300	.04075	.05045	
28	0.0126	160	2,067	.06479	.08022	
30	0.0100	100	3,287	.10300	.12760	
32	0.00795	63.21	5,227	.1638	.2028	
34	0.00630	39.75	8,311	.2605	.3225	
36	0.00500	25.00	13,210	.4142	.5129	
38	0.00396	15.72	21,010	.6585	.8154	
39	0.00353	12.47	26,500	.8304	1.028	
40	0.00315	9.89	33,410	1.047	1,296	

(Figure 154) of special form, designed to make a good electrical and mechanical connection with the various units. These terminals should always be soldered to the ends of the wire so that there is no chance of corrosion or looseness. In case it is necessary to attach a wire and no terminal can be fitted, the work may be done by baring the end for a short distance and, after bending the end into a loop, dipping it into solder so that it is made solid enough to prevent loose strands from forming. The loop should then be placed on its connection in such position that it wraps around in a right-hand direction, and so that tightening of the

Figure 154.—Wire Terminals.

screws will tend to coil the wire closer around the terminal post in place of unwrapping it.

After wiring has been attached to the terminal posts, the fastening screws should be made tight and should preferably be locked in position with wire or by soldering. While this method makes it harder to remove the parts, it also prevents the commonest of all troubles, looseness.

AMMETERS AND VOLTMETERS

Indicating instruments on the car include ammeters, voltmeters, and indicators. As a general rule the construction of an ammeter does not differ materially from that of a voltmeter. In the case of the ammeter the flow of current is allowed to continue without appreciable resistance, while with a voltmeter there is practically no flow through the instrument except the

fraction of an ampere required to operate the meter's movement. The ammeter contains a low resistance shunt connected in parallel with the meter's movement. The voltmeter contains a high resistance connected in series with the movement of the meter.

Ammeter.—If an ammeter scale is marked "Charge" on one side of the scale and "Discharge" on the other

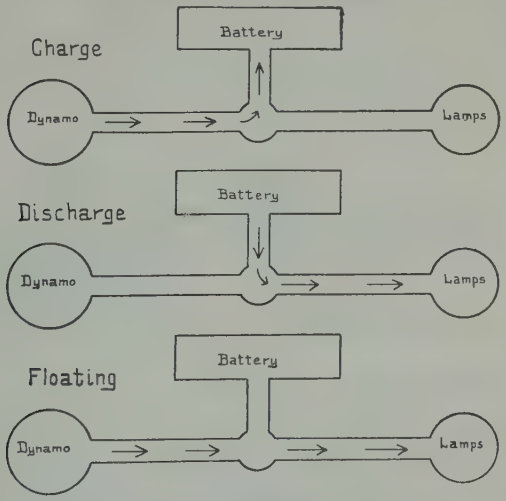


Figure 155.—Current Flow Between Battery, Dynamo and Lamps. Top: Dynamo Running, Lamps off. Center: Dynamo Idle, Lamps on. Bottom: Dynamo Running, Lamps on.

side, the terminals should be connected to the wires so that the pointer swings to the discharge side with lamps turned on while the engine is idle.

An ammeter should be so connected that it will measure all of the current flowing into the battery from the dynamo, and so that it will measure all current leaving the battery, except that used for starting.

An ammeter sufficiently great in capacity to measure the large flow during the cranking operation would have a scale too coarsely divided to measure the small currents used for charging and lighting. It is therefore necessary to find a wire on the car that carries all of the charging current and all of the lighting and other accessories' current, but none of the starting current. This may usually be done by following either one of the large battery wires to the starting switch terminal which also carries a second small cable, then attaching the meter in this small cable as near to the switch as possible. In Figure 155 such

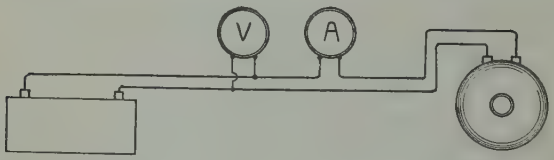


Figure 156.—Voltmeter (V) and Ammeter (A) Connection.

a connection would be in the line down from the battery to the dynamo and lamp circuits.

Voltmeter.—When voltmeters are mounted as part of the equipment of the car they are attached to the positive and negative sides of the charging circuit between generator and battery, usually between the generator and the cut-out, so that they are disconnected from the battery with the engine idle and the cut-out open. An ammeter in series and a voltmeter in shunt are shown in Figure 156. To attach a voltmeter correctly it will be necessary to make an attachment from one meter terminal to a connection between the cut-out and the generator brushes. Then the other meter terminal may be grounded with a one-wire

system or attached to the other generator terminal with a two-wire system. The meter will then indicate generator voltage whenever the generator runs, and charging voltage whenever the cut-out is closed.

Indicators.—As shown in Figure 157, these instruments have faces marked "Charge" and "Discharge," but without any graduations for amperes. Their construction is somewhat similar to that of an ammeter. They are sometimes made with conductors heavy enough so that the indicator may be connected in a line carrying starting current.

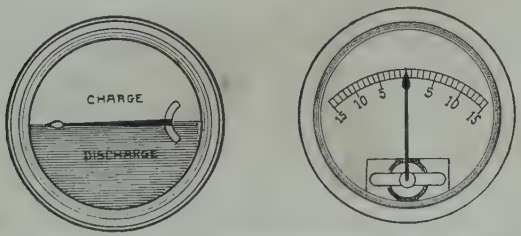


Figure 157.—Indicator (left) and Dash Ammeter (right).

Indicating Instrument Faults.—Because of the fact that ammeters, voltmeters, etc., are primarily designed to tell what is happening and to aid in locating trouble, it should not be assumed that these units themselves are free from error. Outside of trouble caused by open, short or grounded circuits and circuits of high resistance in the wiring and terminal connections of these instruments, they may develop trouble within their mechanism. Should an ammeter be subjected to a current much greater than it is designed to carry, such as would be the case were an ordinary instrument connected in the starting cir-

cuit, the current-carrying coils would be burned out and the meter would have to be rebuilt before further use could be made of it. An ammeter or voltmeter of the permanent magnet type, such as ordinarily employed, will lose its accuracy if exposed to heat, sudden jars or a strong magnetic field. The first and most apparent effect of such a happening will be a sluggish action of the indicating hand. The hand will move slowly from place to place on the dial, and will not return to zero until jarred, if at all. It is quite frequently found that a meter hand does not return to the zero point when current flow or pressure is removed, yet the action may be satisfactory in all other ways. To overcome this difficulty, to which all meters are more or less subject, high-grade instruments are provided with a "zero center" adjustment by which the tension of the springs controlling the movement may be changed.

When an ammeter or voltmeter is in proper working order, the hand should remain at zero with one or both of the wires removed from its terminals. Should there be an error at this time, the number of amperes or volts should be noted and allowed for in future readings. The hand should move quickly from point to point and should come to rest within a reasonable time.

SWITCHES

The amperage or current that is carried by the circuits of the automobile lighting system is considerably greater than that carried in the ordinary house lighting system. The amount of light in candlepower may be no greater or it may be about the same. This would mean that the power in watts would be about

the same, and because of the low voltages in use with car lighting systems, the amperage must be correspondingly higher. The contact surfaces of lighting switches for use on cars must be made large and of material that will stand the sparks that are formed when the circuits are broken.

Many types of separate lighting switches are in common use. One of these types carries two small push-buttons on its face-plate, one button serving to close the circuit and the other to open it. They are mounted at opposite ends of a pivoted arm so that pushing one of them in will cause the other one to come out. The contacts are actuated by spring-operated arms so that the circuit is broken quickly enough to prevent excessive arcing. Another type very similar in construction makes use of but one button, this usually being pulled out to close the circuit and turn on the lights and pushed in to turn them off. One switch is provided for each circuit that is to be controlled, and the switches are usually assembled with the proper number attached to one face-plate that appears within reach of the driver.

A third type is that known as the rotary switch, the principle of which is shown in Figure 158. The switch handle may be turned back and forth to secure various combinations, or it may always be turned in one direction until the desired combination is reached. Many variations will be found in this type construction. These switches for automobile work are made so that the several combinations of lights are given by successive quarter turns or sixth turns of the button. A combination in common use for the four quarters would be as follows: All Off. Head Lights Dim, Tail Light Bright. All Lights Bright. Side Lights and

Tail Light On. The next quarter would then bring the switch back to the "All Off" position.

Many combination switches are in use that care for the lighting, starting and ignition circuits by bringing two of them or all three to the one-switch unit. The combination switch that serves for lighting and ignition is in most common use, this type usually being fitted with separate buttons or levers for the two functions. This makes it in reality two switches of

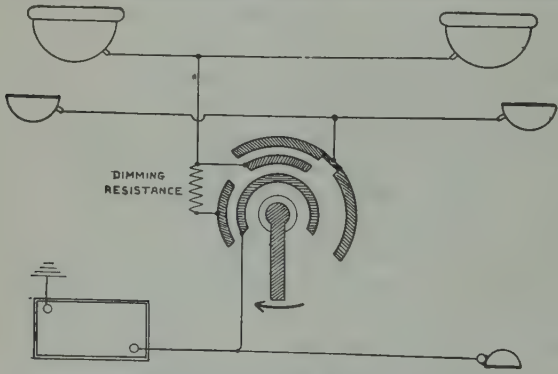


Figure 158.—Rotary Lighting Switch Construction.

any suitable form carried in one housing. Switches are also in use that have but one lever or button for both lighting and ignition. With the switch button in place, the ignition is turned on, and with the button moved into various positions the different lighting combinations are secured. Removal of the button with any lighting combination in use will then stop the ignition, but will allow the lights to remain lighted as with the button in place.

Combined starting and ignition switches are in general use with motor-dynamos that do not make use of

an automatic cut-out. (See Figures 120 and 122.) These switches usually have three positions, although they are also made with but two changes, "On" and "Off." With the three-position switch the points are marked "Off," "Neutral" or "Idle," and "Start" or "Run." In the "Off" position the ignition is inoperative and the motor-dynamo is disconnected from the battery. In the "Start," or "Run," position, the ignition is turned on and the battery current is allowed to flow to the motor-dynamo, making it act as a starting motor. If the switch is left in this position the motor-dynamo will act as a dynamo when the engine speed is sufficiently high. In the "Neutral," or "Idle," position, the ignition is turned on, but the motor-dynamo is disconnected from the battery, so that no starting motor action will take place. Some switches have a "Neutral" position in which starting motor action can take place, but arranged in such a way that the field circuit for the dynamo is open and the unit cannot charge the battery. This last arrangement is designed to prevent excessive battery charge on long runs, such as in touring.

Combined starting, lighting and ignition switches are also made in various forms. They may be simply a collection of the separate switch units in one case, or they may be designed to produce starting, lighting or ignition by movement of one lever or button in different directions. Such switches are marked on the face-plate so that the operator need only follow the directions to secure the desired result.

FUSES

A fuse consists principally of a short length of wire of such a composition that it will carry a certain

amperage with very little resistance, but when this amperage is exceeded will rapidly rise in temperature to such a point that it will melt and thus break its connection in the circuit and prevent further flow of current. Fuses are used in either the lighting or charging circuit and oftentimes in both. The wire may or may not be enclosed inside of a small tube. When unenclosed they are called open-fuse links, or simply fuse wire. This form is not safe to use around a car because of the danger of fire from the exposed flash should the fuse burn out. Enclosed fuses are called cartridge fuses and may be surrounded with a tube of fibre or one of glass (Figure 159). With glass-

Figure 159.—Glass and Fibre-Bodied Cartridge Fuses.

enclosed fuses it is very easy to discover when one has been burned out by looking through the glass. With fibre covering, burning of the fuse causes a small blackened spot to appear at some point along the tube, usually at the center. Fuses may always be tested by attempting to pass current through them and at the same time through a lamp or meter of some kind. Failure to secure a flow indicates a blown fuse, and it will be necessary to replace that one with a new one. Their cost is so low that there is no economy in attempting to renew the fusible wire.

Fuses are always rated according to the amperage they will carry without burning out and according to the voltage with which they operate. The proper size to use will, of course, vary with the voltage and

candlepower of the lamps supplied or with the flow required through the charging circuit, field circuit or other path of current in which they are placed. In the absence of definite instructions the following sizes may be used. These are calculated for a six-volt system. Higher voltages will require a smaller amperage and fuses of lower rating.

Head lamps.....15-ampere
Side lamps only.....5- to 8-ampere
Tail and dash lamps.....5-ampere
All lamps.....20-ampere
Horn 15-ampere
Dynamo field fuses.....3- to 10-ampere
Charging circuit fuses .....20- to 45-ampere

A fuse should never be replaced with one of a larger size than that specified by the car or equipment manufacturer, and should never be replaced with wire or nails. Fuses are only used at points through which an excessive flow of current may occur, and which will cause more or less serious damage when it does occur. Replacement with such substitutes in the lamp lines may result in burning out all the bulbs affected; in the dynamo field circuits the result will be burned-out dynamo field windings, and in the charging circuits the result will probably be a ruined battery.

Cartridge fuses are held in spring clips at each end. These clips should be set so that they hold the fuse without looseness, and the contact surfaces between fuse and clip must be clean and bright. A particle of dust at this point will prevent any flow of current. Trouble may be experienced with the fastenings between fuse clips and their bases or between

the clip and the wire end to which it is attached. These points should be examined in case of an open circuit or a greatly diminished flow through a circuit in which fuses are used. In case the ends of a cartridge fuse or the surfaces of the fuse clips are found dirty or corroded they should be cleaned and brightened with sandpaper.

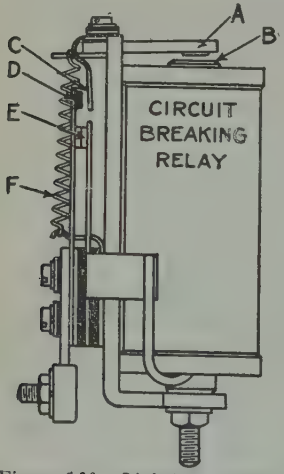


Figure 160.—Lighting System Circuit Breaker (Delco)
A—Magnet Armature.
B—End of Magnet Core.
C—Arm Attached to Armature.
D—Bumper on Movable Contact Arm.
E—Circuit Opening Contacts.
F—Spring.

CIRCUIT BREAKERS

The disadvantage in the use of fuses for protection is that spare ones of the right size must be at hand for purposes of replacement. Unless the right fuse can be easily obtained, it is a great temptation to replace it with a length of wire. To obviate this difficulty a magnetic circuit breaker is often used which opens the circuit as soon as there is an excessive amperage flowing. (See Figure 160.) These circuit breakers consist of an electromagnet around which passes the current flowing in the circuit. Carried at a point near enough the magnet core to be influenced by it is a small armature, and to this armature is attached, either directly or by springs, one contact through which the current flows on its way around the magnet and through the circuit. A stationary contact is mounted so that

it touches the movable one, and as long as they remain together the current flow can continue.

Should the amperage passing around the magnet become too great for safety, the armature is attracted and the contacts are separated, because the magnetism produced will overcome the strength of the spring that normally holds the contacts together. The circuit breaker contacts may then remain apart or come together again, depending on the design. With no other parts than those described, the contacts will immediately come together after they once open, because the flow around the magnet is stopped when they separate. With no flow around the magnet the spring will again cause the circuit to close, and the action will be repeated rapidly, with a continuous clicking or buzzing noise, until the cause of the excessive flow is eliminated.

Other forms of circuit breakers are so constructed that the movable arm is caught and held by a latch so that the circuit is not again closed after once being opened. A handle or trigger is arranged so that the driver may release the latch and allow the breaker to return to its operative position. The adjustment of a circuit breaker spring should never be changed, because this would have the same effect as if fuses were replaced with others of higher capacity. The tension is just right for the current to be carried, and any increase will probably result in damage.

LAMP DIMMING

In most localities it is required by law that lamps of more than four candlepower must have their light controlled in such a way that no direct rays will be more than forty-two inches above the level ground at

a point seventy-five feet ahead of the car when it is fully loaded. In a few cases the requirements differ, but the foregoing is the general rule.

These requirements may be met in various ways. Extra bulbs may be used or additional small lamps may be fitted. The voltage at the bulbs may be reduced or the bulb may be shaded to reduce the light. A special reflector may be fitted or the reflector may be tilted. The most generally used method is that of fitting a type of lens that deflects, diffuses, shades or colors the light rays so that the glare is eliminated. The forty-two inch height at seventy-five feet is illustrated in Figure 162.

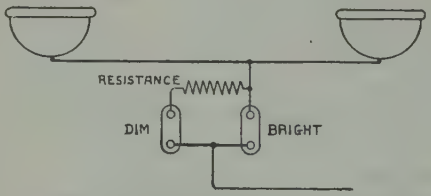


Figure 161.—Resistance Method of Lamp Dimming.

Reduced Voltage.—The voltage at the lamp bulbs is often reduced by inserting a resistance in the circuit with a switch control so that the resistance may be placed in series with the lamps for dimming, or cut out of the circuit for bright lights as shown in Figure 161. Resistance dimmers in their practical connections may be seen in many of the wiring diagrams.

It is also possible to connect two lamp bulbs in series with each other so that each receives half the voltage of the battery as shown in Figure 163. Their candlepower in series is reduced to less than half the value that was secured with the bulbs in parallel as in

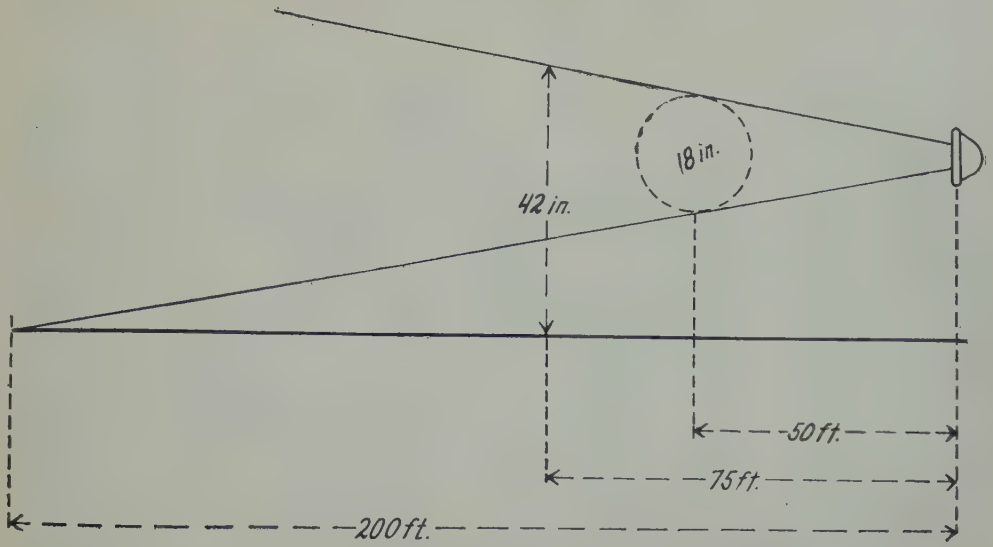


Figure 162.—Usual Legal Requirements for Lamp Dimming.

the usual connections. Wiring which allows the lamps to be placed either in series or parallel is also shown in Figure 163. This makes use of a double-pole, double-throw switch having its blades pivoted at *N*

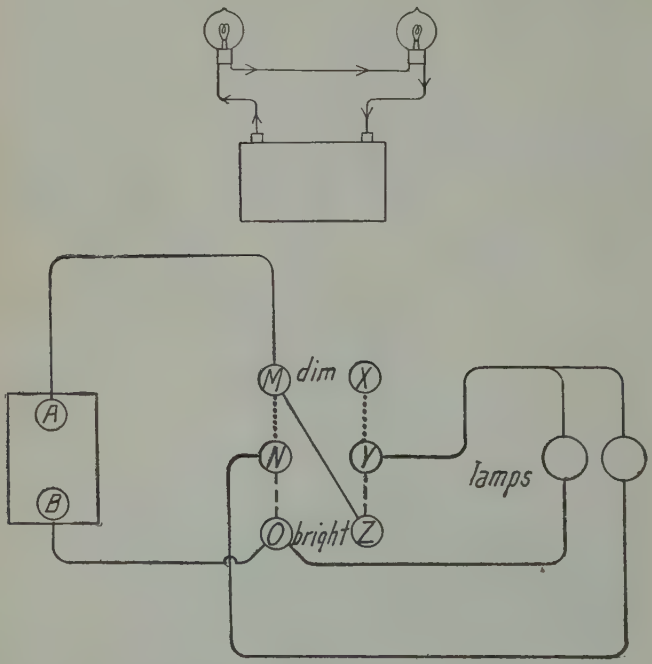


Figure 163.—Series-Parallel Method of Lamp Dimming.

and *Y* and able to swing to *M-X* for dimming or to *O-Z* for bright lights. In the bright position battery current flows from *A* to *M*, to *Z*, to *Y* and to both lamps. From the lamps, the current returns to *N* and to *O* and from *O* back to the battery. In the dim posi-

tion battery current flows from A to M, to N to one lamp and through it and the other lamp to O and back to the battery, all other paths being opened by the switch.

Using Extra Bulbs.—In many equipments, the large bulbs are used only when a bright and glaring

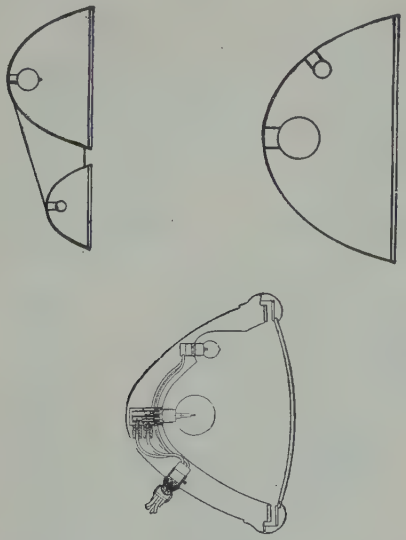


Figure 164.—Use of Small Bulbs for Dimming.

light is permissible, while smaller ones are employed under all conditions that call for dimming. These smaller bulbs may be in a separate housing or an extension housing on the large lamps, they may be mounted at an out-of-focus point on the main reflector or a small reflector may be formed as a part of the large one, all three methods being shown in Figure

164. This, of course, is not a dimming method, strictly speaking.

Control of Light at Bulb.—With a bulb in exact focus as at the upper left of Figure 165, the light rays will travel straight ahead. With the bulb back of the focus as in the upper right of the drawing, the

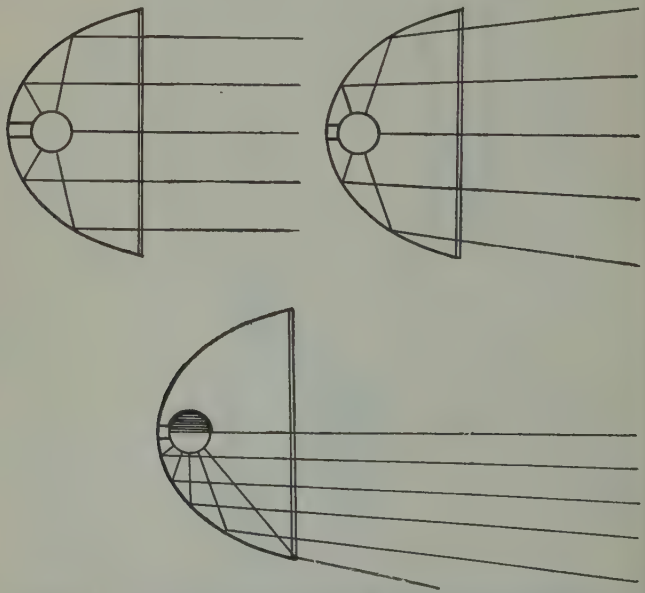


Figure 165.—Using a Reflecting Shield for Dimming.

rays from the upper part of the reflector will turn upward while those from the lower part turn downward. If a reflecting shield is then placed over the top half of the bulb, the upward turning rays will be reflected back to the filament and will then be thrown downward from the lower half of the reflector; thus pre-

venting and direct rays above a certain height determined by the bulb position.

Reflectors and Lenses.—Figure 166 shows one type

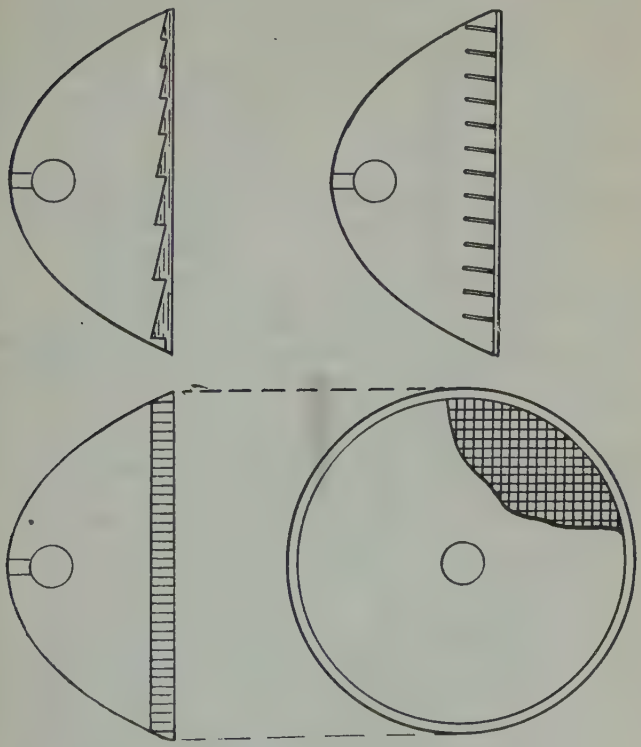


Figure 166.—Lenses to Deflect Light Rays.

of prism lens, another with deflecting shutters, and a third with a series of small openings that prevent spread of the rays. In Figure 167 are many convex surfaces diffusing all the rays, also a lens carrying

a colored visor or shade near the top to prevent upward rays. In Figure 168 is a reflector having its upper half at a different angle from the lower

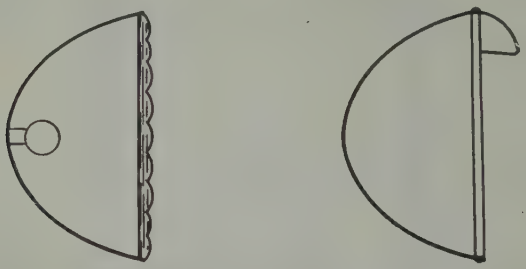


Figure 167.—Diffusing Lens and Shading Visor.

half so that the beams from above are reflected downward. Still other lamps are made to tilt the whole

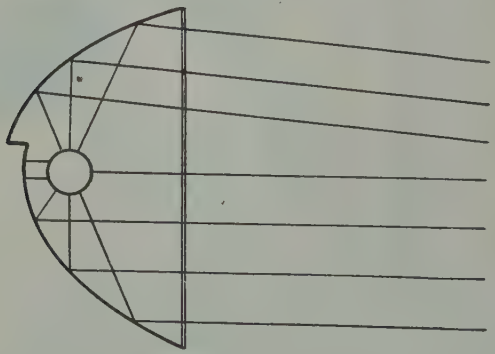


Figure 168.—Reflector with Top Half Offset.

reflector or the whole lamp downward. Colored glass also is used in both plain and prismatic reflectors to prevent blinding glare.

REVIEW OF CHAPTER VI

LAMPS AND WIRING

Lamp bulbs are specified by single-contact (S. C.) or double-contact (D. C.), by their voltage, and by their candlepower or amperage.

With six-volt systems, **6-8 volt bulbs** are used; with twelve-volt systems, **12-16 volt bulbs** are used; and with eighteen-volt systems (now obsolete), **18-24 volt bulbs** are used. Two **3½ volt bulbs** may be used in series on a six-volt battery. **Ford cars with magneto lighting use 9-volt bulbs.**

Wiring systems are of the **one-wire** ground return type or of the **two-wire** insulated return type. **Three-wire** systems are no longer used.

Wires are specified by their **gauge size** and the kind of insulation. The diameter of the conductor decreases as the gauge numbers increase.

All automobile wires should have **stranded conductor.**

Ammeters should be connected between the large battery terminal at the starting switch and the lines to the generator, lamps and accessories.

Voltmeters should be connected across the generator brushes or from the generator to ground between the generator and the cut-out.

Circuit breaker springs should not have their tension changed to overcome opening caused by shorts or grounds.

All **wire ends** should be fitted with metal terminals.

Light from the lamps may be **dimmed** by inserting **resistance** in series with the bulbs. The current used for heating the resistance is wasted and this method of control is uneconomical.

Most localities require **control of the light rays to prevent glare from affecting approaching drivers.**

CHAPTER VII

THE STARTING SYSTEM

STARTING MOTORS

A typical starting motor construction is shown in Figure 169 and it will be found to differ but little from that of a dynamo. The field coil windings are much heavier than for a dynamo and they are connected in series with the armature rather than in shunt. The armature windings are correspondingly heavier because of the heavy currents that must be carried.

The starting motor consists of a housing with field poles and field windings, of an armature with its commutator and brushes together with the necessary bearings. A side section showing the armature windings is shown in Figure 170. At the present time most of the starting motors are separate units, although a few motor-dynamos are in use. As a general rule, either a separate motor or a motor-dynamo run at higher speed than the engine and are connected to the engine by some form of drive. Motor-dynamos of U. S. L. make have been mounted directly on the engine crankshaft and run at engine speed as shown in Figures 171 and 172. Typical field and armature connections are shown in Figure 173.

Motor Performance.—When the starting motor is connected to the battery there is a large amperage

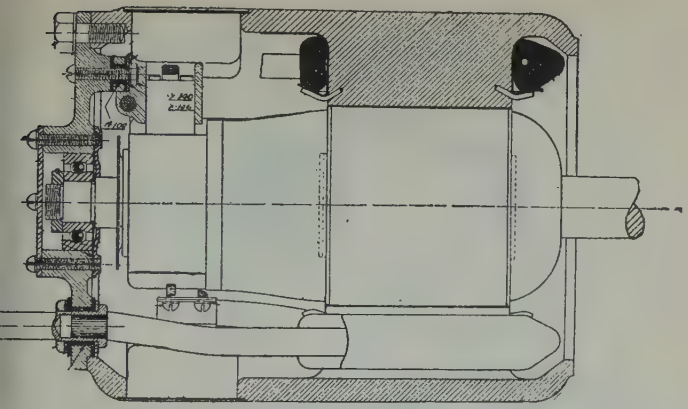


Figure 169.—Starting Motor Construction.

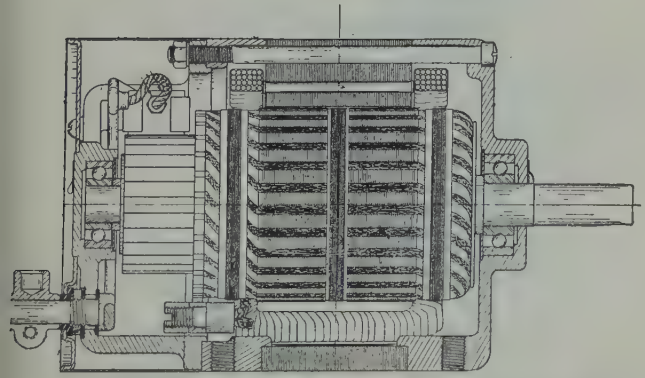


Figure 170.—Details of Starting Motor. (National)

flowing through the circuit. It requires considerable power to crank an engine, and at the low voltages in

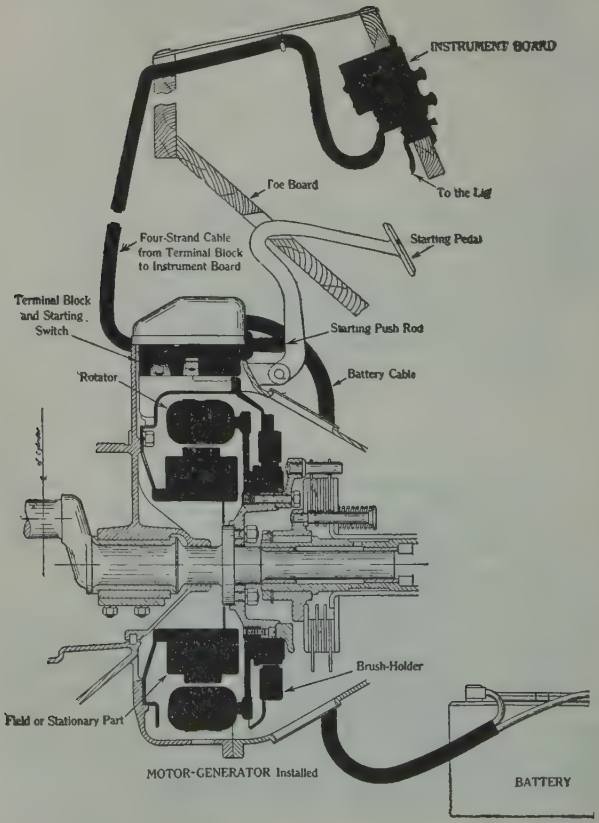


Figure 171.—U. S. L. Direct Connected Motor-Dynamo.

use a large amperage is needed in order to give the necessary power in watts. The power of a starting

Figure 172.—U. S. L. Armature and Fields.

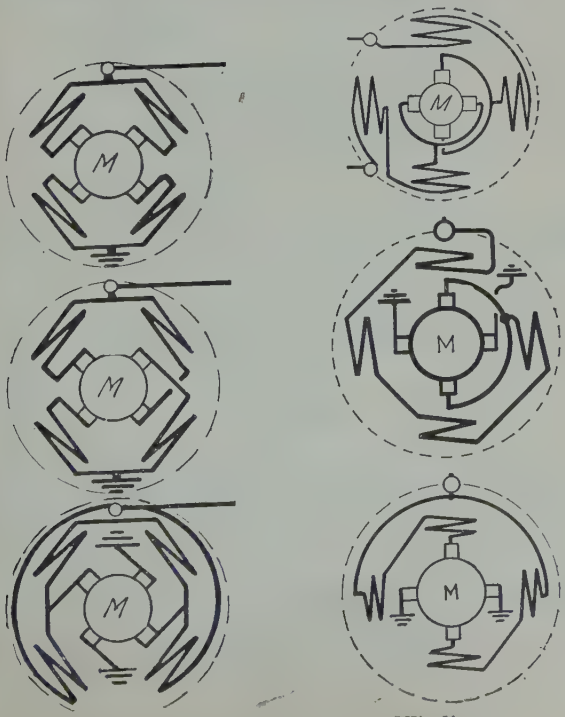


Figure 173.—Starting Motor Windings.

motor is usually measured in foot-pounds; a foot-pound being a turning effort that will lift one pound at the end of an arm one foot long attached to the motor armature shaft. The relation between the amperage in the starting circuit and the foot-pounds torque or turning effort is shown in Figure 174, this curve representing the average performance of many

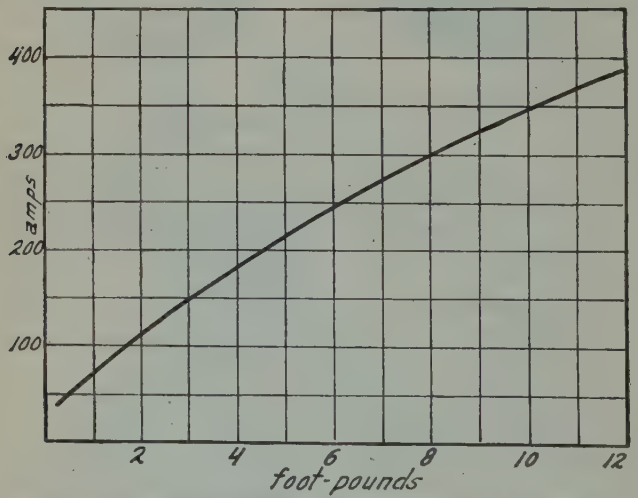


Figure 174.—Relation Between Amperage and Power for Starting.

starting motors. The torque falls off slightly at high amperages; that is, the pull is not in exact proportion to the amperage. This is due to the fact that the voltage falls off with an increase in pull or load so that the watts and power for a given number of amperes become less.

The usual relation between the amperage and the armature shaft speed is shown in Figure 175, this

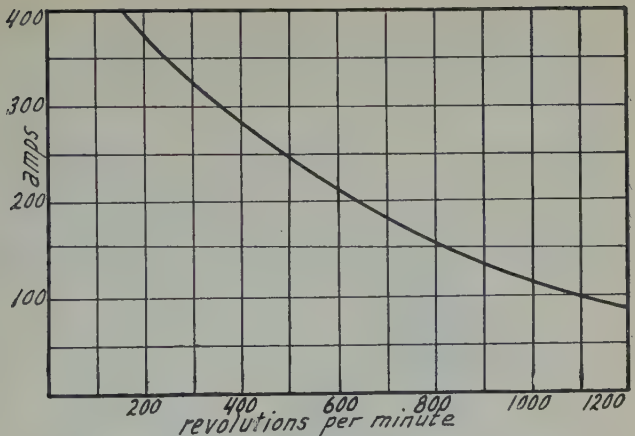


Figure 175.—Relation Between Amperage and Cranking Speed.

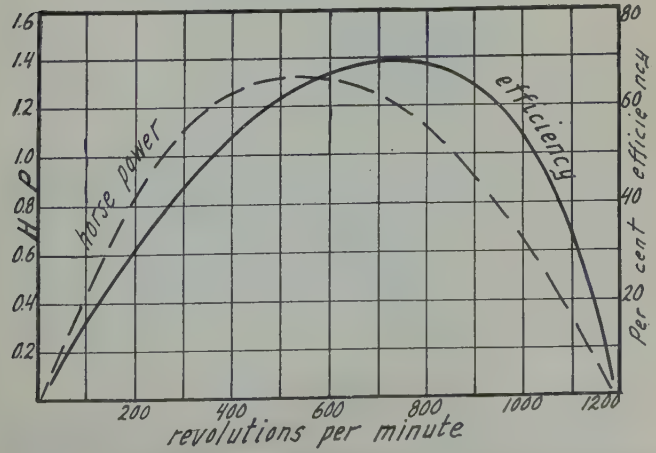


Figure 176.—Horsepower and Efficiency of Starting Motors.

also being a composite from many similar curves. It will be seen that as the speed decreases, denoting an increase of load and pull, that the amperage increases to furnish the additional power required to handle the load.

The horsepower of a starting motor increases with the speed up to a certain point about midway of the total range of speed from zero to maximum, then the power falls off with further increase of speed. The

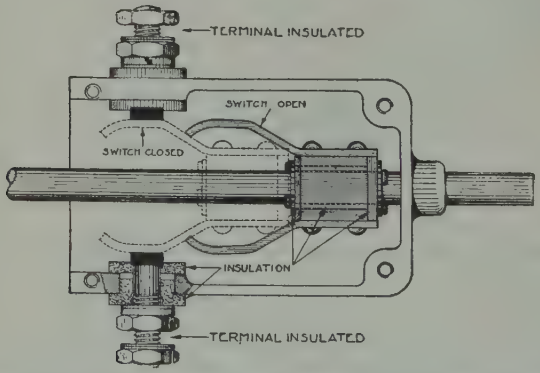


Figure 177.—An Insulated Starting Switch. (Gray & Davis)

efficiency of a starting motor rises with the speed until it reaches its highest point of about 60 to 70 per cent at medium speeds. The efficiency then falls off gradually until at the highest possible armature speeds it drops nearly to zero. Horsepower and efficiency curves are both shown in Figure 176.

STARTING SWITCHES

Starting switches are generally quite simple in construction with contacts and current carrying parts of

large area and capacity in order to handle the high amperage without too great loss. The starting switch terminals are often used as a convenient junction

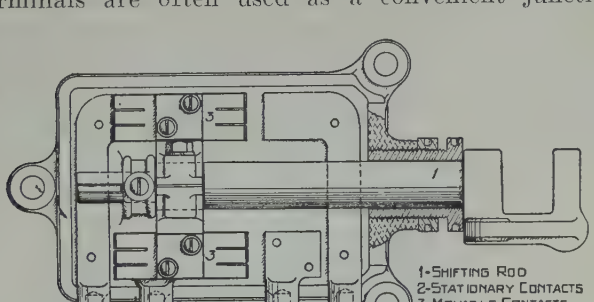


Figure 178.—A Double Pole Starting Switch. (Leece-Neville)

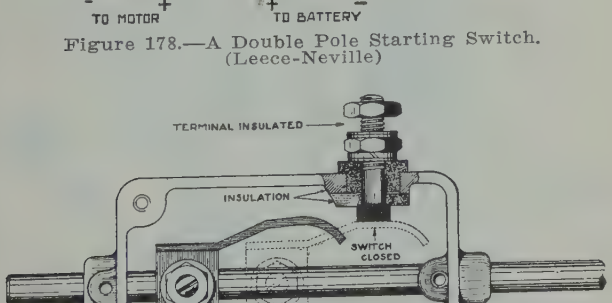


Figure 179.—Switch With V Contact Blade. (Gray & Davis)

point at which to connect the charging and lighting lines to the battery leads. It will generally be found that the large battery cables run as far as the starting

switch and starting motor, and that the other lines are run from the switch to other parts of the car.

Starting switches may be built with one side grounded when used for one-wire or ground return systems, this ground serving to connect one side of the battery with the metal of the car. A ground connection is not always depended upon to carry the starting current, and even with the grounded switch, a cable may be run to the battery for both sides of

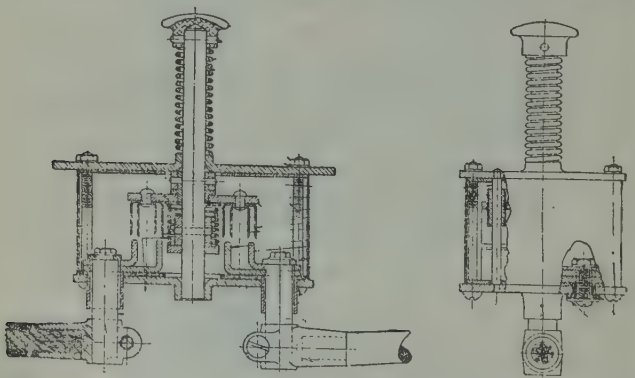


Figure 180.—Ring or Crown Contact Switch. (Auto-Lite)

the starting circuits. A switch with both sides insulated is shown in Figure 177.

Most starting switches are of the single pole type in which but one side of the circuit is opened and closed, but in a few cases, such as the example in Figure 178, both the positive and negative sides of the circuit are controlled through the switch, which is then of the double pole type.

Switch Contacts.—Many types of contacts are used to complete the circuit through starting switches.

In Figure 179 is shown a V type of moving plunger which operates in a switch having one of its terminals grounded, this being similar to the insulated switch shown in Figure 177. A switch having ring or crown-shaped contacts is shown in Figure 180. A sliding ring type of switch is shown in Figure 181, the sliding rings being carried on the plunger and embracing the

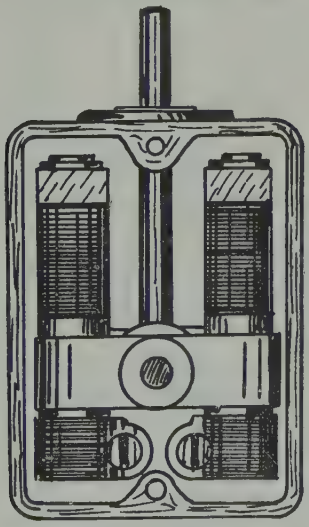


Figure 181.—Sliding Ring Starting Switch. (Remy)

stationary members to which the cables are attached.

Figure 182 shows a switch having flat contacts. In the particular example illustrated the electromagnetic cut-out is carried with the starting switch.

Switches having knife blade contacts are shown at the bottom of Figure 126. A type of switch with sliding contact fingers moving over flat surfaces is

shown in Figure 183. All of the switches so far mentioned are of the single contact type in which the whole current flow is allowed on the one contact.

One or more of the starting motor brushes may be raised from its commutator, then lowered into contact

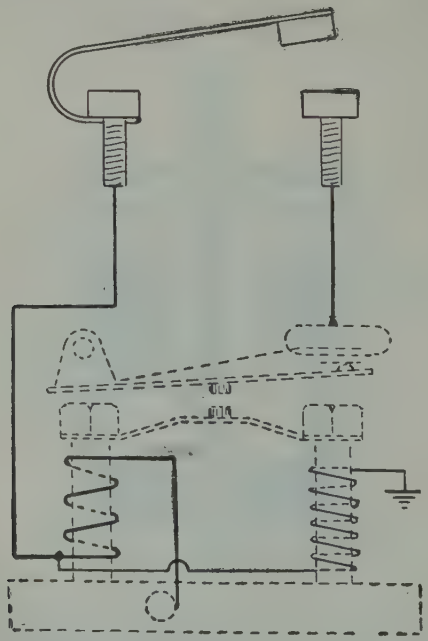


Figure 182.—Starting Switch and Cut-Out. (Westinghouse)

when the starting circuit is to be completed; the brush thus acting as a switch. One such construction, used with Delco motor-dynamos, is shown in Figure 184. It will be seen that the right hand brush is held away from the commutator by a rod acting against the

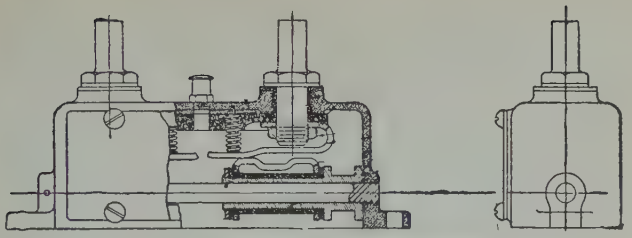


Figure 183.—Sliding Contact Starting Switch. (Auto-Lite)

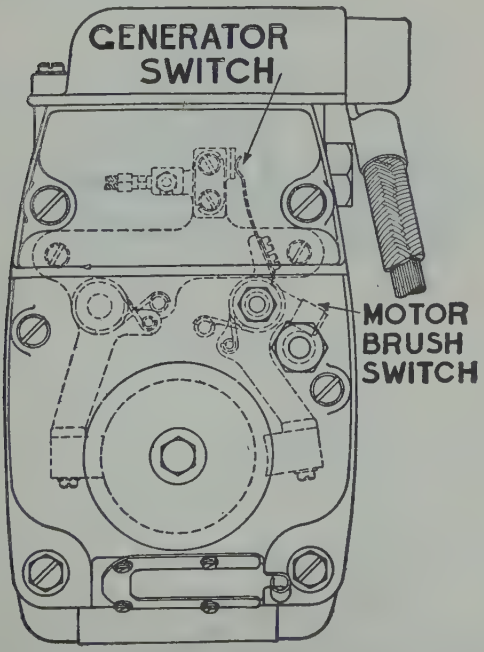


Figure 184.—Motor Brush Starting Switch. (Delco)

upper arm of the brush holder. Moving this rod with the starting pedal allows the brush spring to press the switch brush against the commutator.

Starting switches sometimes have more than one set of contacts, even with the systems using but one voltage for both charging and starting. A switch is shown in Figure 192 with which current is first allowed to flow through a resistance in order to set the gearing in

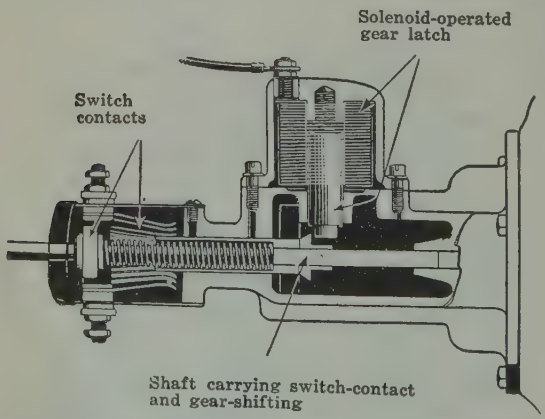


Figure 185.—Magnetic Release on Starting Switch.

motion for easy meshing. Starting switches are also made that contain auxiliary contacts which open the charging circuit while the motor-dynamo is in use as a starter.

Switch Movement.—Most starting switches are positively operated either by foot or hand. They are designed to be placed in full contact by pressure, and are opened by a spring upon release of the pressure. Sometimes the starting switch is operated through a

spring as shown in Figure 190 and in such a way that the gear meshing is rendered easier.

One Auto-Lite switch is controlled by a solenoid as in Figure 185. A pedal moves the gear shift rod, compresses the spring and closes the switch. The solenoid lifts the latch and releases the gear shift.

Magnetic Switches.—Several Westinghouse systems have made use of a starting switch that is operated by an electromagnet, the electromagnet being energized when the driver presses a button conveniently located at some point within his reach. The connections for such a switch are shown in Figure 186, and the operation is as follows: When the pushbutton is pressed, current flows from the grounded side of the battery to the button, through the button and to the electromagnet winding in the starting switch. From the magnet in the switch the current passes to the dynamo, then back through a connection made in the switch housing, and to the other side of the battery. The pull of this electromagnet in the switch attracts the armature of the magnet, and this armature carries the contact piece for the main switch contacts. With the main contacts closed, the current flows through the switch and to the starting motor. In series with the starting motor circuit is a solenoid through whose windings passes the core attached to the gear meshing rod, and the gears are brought into mesh by the action of this solenoid. The starting button causes the switch magnet to become energized, and the flow thus allowed to pass through the switch energizes the solenoid so that the gears are meshed. As soon as the engine starts to run, it drives the dynamo, and the current from the dynamo that passes to the battery flows in a direction opposite to that

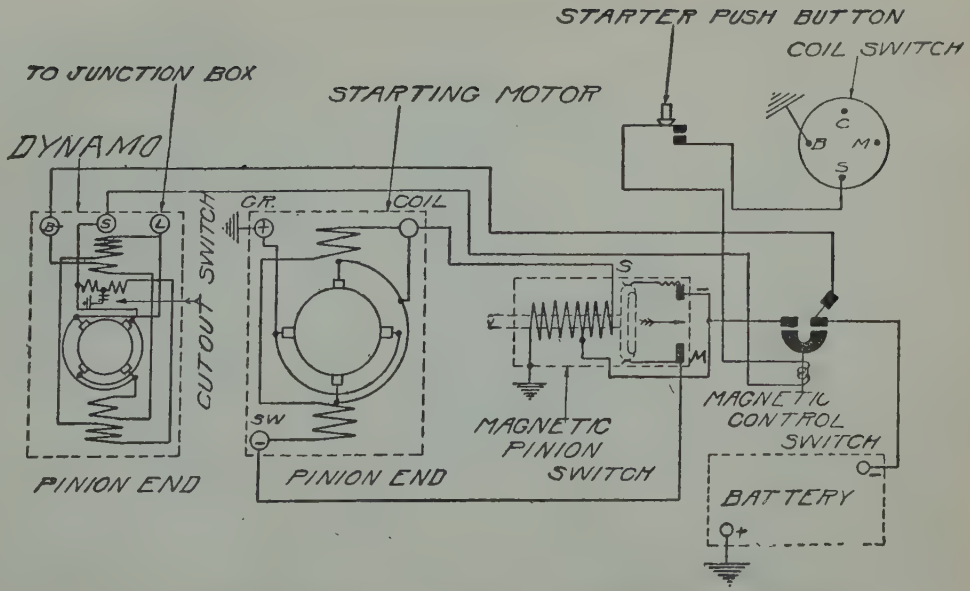


Figure 186.—Magnetic Starting Switch and Gear Shift (Westinghouse).

allowed by closing the starting button with the dynamo idle. Because of this reversal of current, the electromagnet in the switch is demagnetized just as soon as the cut-out closes, and the starting switch contacts are immediately opened. No amount of pressing on the start button can cause the starting switch to close and the gears to mesh with the engine running for the reason that the current for this operation cannot pass to the electro magnets while the cut-out is closed.

Motor-Dynamo Switches.—Motor-dynamos may be divided into two classes, one of which will include those machines that complete the connection between battery and electric unit for starting and then allow this connection to remain closed while the motor-dynamo speed becomes high enough to cause battery charging as illustrated in Figure 126. The other class includes those machines that complete the connection for starting through one of the usual forms of starting switch and complete the charging connection through an electromagnetic cut-out. The latter system is always used with installations that use a high starting voltage and a comparatively low charging and lighting voltage, because it would be manifestly impracticable to allow a machine that generates a low voltage to remain connected to the battery with the battery sections so connected as to produce a high voltage, as used in starting.

The connections made by switches which establish a circuit that is maintained for both starting and charging have been described in Chapter IV under "Cut-Outs." Practically any of the types making a single contact for starting may be used with dual voltage equipments.

Commutating Switches.—The type of switch used with motor-generators that use a starting voltage

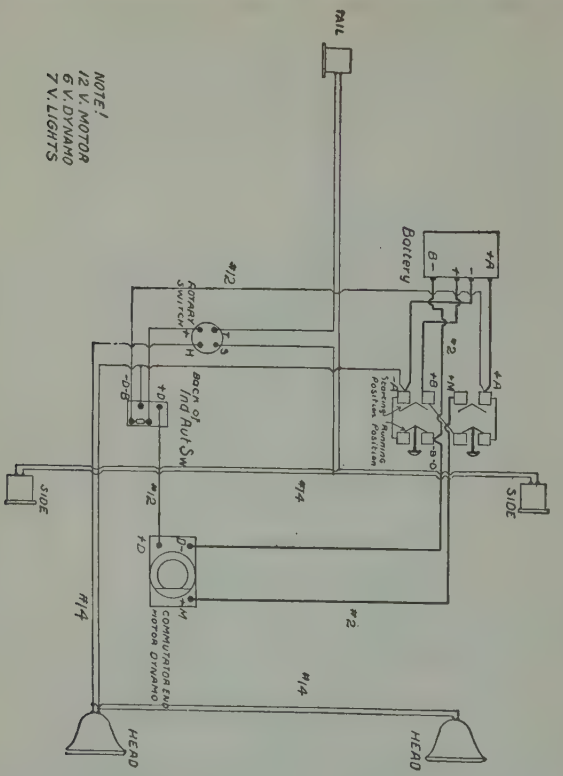


Figure 187.—Splitdorf Commutating Starting Switch System.

higher than the charging voltage is called a commutating switch because it changes the connections for battery and electric machine to allow either one

of the functions to take place. With such switches in the idle or running position, the sections of the battery are connected in parallel or multiple, so that the voltage of the whole battery will be no greater than one section and will be correct for lighting and charging. With the switch in the starting position, the battery sections will be connected in series with each other, and the voltage of the whole battery will be equal to the voltage of one section multiplied by the number of sections used.

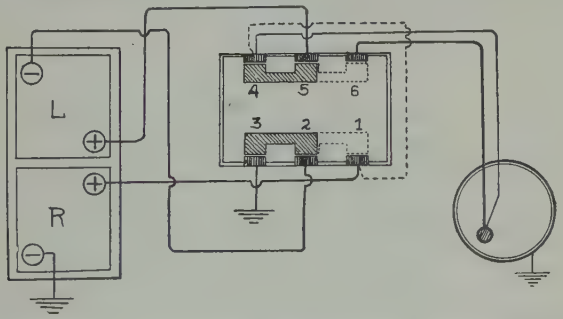


Figure 188.—Simms-Huff Commutating Starting Switch.

A Splitdorf motor-generator commutating switch is shown in Figure 187. With the switch in the position indicated, the two halves of the battery are connected in parallel so that six-volt charging and lighting is possible. When moved to the starting position, the battery halves are placed in series for twelve-volt cranking. Figure 188 shows a Simms-Huff commutating switch, the full lines indicating the six-volt running position and the dotted lines the twelve-volt starting position. Figure 189 shows another similar switch of Wagner make.

APPROXIMATE STARTING AND RUNNING TORQUE IN FOOT POUNDS REQUIRED FOR AUTOMOBILE ENGINES

Torque is found at intersection of lines for bore and stroke. The table is based on four cylinder engines. Six cylinder engines require 1½ times the torque given, eight cylinder engines require twice as much and twelve cylinder types requires three times the torque.

Heavy faced figures give torque required for starting the engine from rest.

Light faced figures give torque required to keep the engine turning.

Bore in Inches	Stroke in Inches										
	3½	3¾	4	4¼	4½	4¾	5	5¼	5½	5¾	6
3	**50**	**53**	**56**	**59**	**62**	**65**	**68**	**71**	**74**	**77**	**80**
	11	11	12	13	14	14	15	16	17	17	18
3¼	58	61	64	67	70	74	77	81	84	87	90
	12	13	14	15	16	17	18	18	19	20	21
3½	65	69	73	77	80	84	87	90	94	97	100
	15	16	17	18	19	20	21	22	23	24	25
3¾	72	77	83	87	91	94	97	100	104	107	110
	17	18	19	20	21	22	23	25	26	27	28
4	81	86	91	96	100	105	109	113	116	119	122
	19	20	21	23	24	26	27	28	30	31	33
4¼	90	94	98	103	108	112	116	119	122	125	128
	21	23	24	25	27	28	30	31	33	34	35
4½	97	102	107	112	116	121	126	131	135	140	145
	24	25	27	29	30	32	34	36	37	39	41
4¾	105	111	116	121	126	131	136	142	147	152	157
	26	28	30	32	34	36	38	40	42	44	45
5	112	119	126	132	137	142	147	153	158	164	170
	29	31	33	36	38	40	42	44	46	48	50

DRIVE RATIOS

The ratio of starting motor speed to engine cranking speed is determined according to the power developed by the motor and the power required to start the engine crankshaft in motion and after being started to keep it in motion at a speed sufficiently high to cause good carburetion and ignition. The power of the

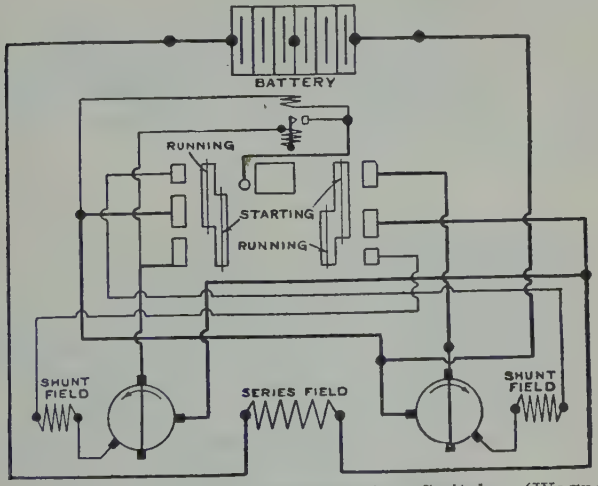


Figure 189.—Drum Type Commutating Switch. (Wagner)

motor depends chiefly on the voltage and amperage of its current, while the effort required for cranking depends chiefly on the number of cylinders and on their bore and stroke.

It requires from three to four times as much power to start an engine from rest as it does to keep it turning after the parts are moving. Average engines require

75 to 150 foot-pounds torque for the break-away and from 20 to 45 foot-pounds to keep them in motion. Average starting motors deliver from 4 to 15 foot-pounds at two to five hundred amperes and six volts. With an engine requiring 108 foot-pounds for break-away and a motor developing 6 foot-pounds, a reduction of 18 to 1 is required. Many reductions will be found to fall around 13, 14, 15 or 16 to 1, these generally giving ample power.

In the case of a direct connected motor-dynamo, it is not possible to use high gear ratios because the speed while generating would be destructive. Motor-dynamo ratios generally fall between two and one-half and three and one-half to one.

BENDIX DRIVE

The majority of present-day cars have their starting motors fitted with a device called Bendix drive, inertia pinion, or screw pinion shift, by means of which rotation of the starting motor armature automatically whirls a small pinion along a threaded sleeve and into mesh with the gear teeth on the rim of the flywheel.

At the top of Figure 190 is shown this device on the end of a starting motor shaft, and at the bottom of this illustration is shown another application with a section cut through the Bendix gear. In the upper drawing, rotation of the screw draws the pinion toward the starting motor, and this is called an inboard mounting. In the lower drawing the rotation of the screw drives the pinion away from the motor, and to provide a support for the end of the screw shaft there is an outer bearing. This is called an outboard mounting.

The construction and action of this drive may be understood from Figure 191. In the upper drawing it will be seen that the motor armature shaft comes

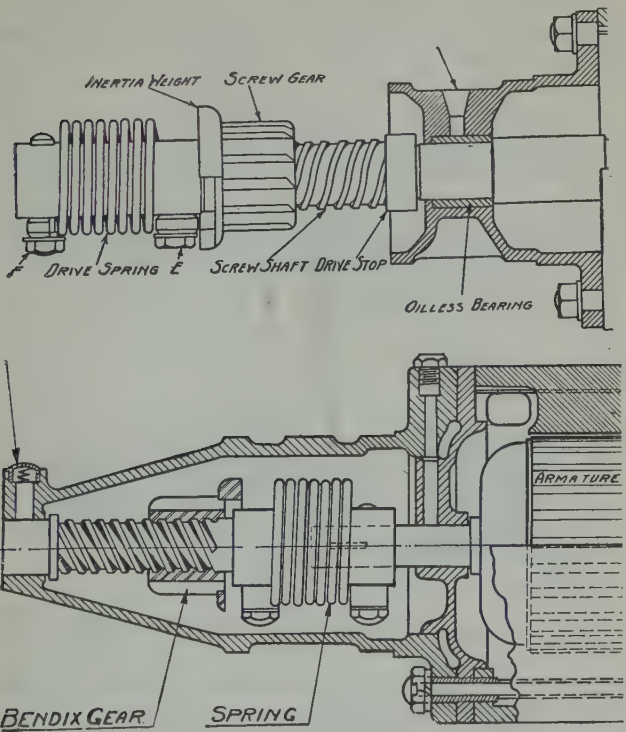


Figure 190.—Bendix Drive Construction. Top: Inboard Mounting. Bottom: Outboard Mounting.

all the way through from the motor (at the right) to the collar bolt at the extreme left. To this collar bolt is attached one end of a coiled spring whose other end, as may be seen in the lower drawing, is

attached to a second bolt. This second bolt passes into the sleeve on which are cut the threads, and the small pinion is mounted on this threaded sleeve.

The armature shaft drives the spring through the collar bolt, the spring drives the sleeve through the second bolt, but there is no other driving connection

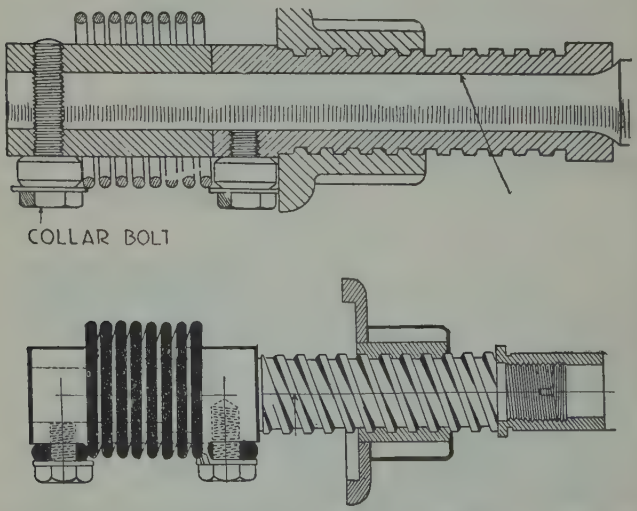


Figure 191.—Threaded Sleeve and Spring Drive of Bendix.

between the armature shaft and threaded sleeve except through the spring.

It will be seen in Figure 190 that there is a weight on one side of the small pinion. When the starting motor armature shaft starts to revolve with the starter switch closed, the threaded sleeve is whirled by the spring. But the inertia weight on one side of the pinion prevents the pinion from starting to revolve

with the threaded sleeve. Since the sleeve thus turns inside the pinion, the threads make the pinion run along the sleeve just as if a nut on a bolt were held from turning while the bolt revolved. This action sends the pinion along the threads until it meshes with the flywheel gear. Should the teeth of the pinion and flywheel gear meet end on, so they could not slide into mesh, rotation of the armature shaft starts to coil the spring and the sleeve turns slightly on the armature shaft until the pinion changes its position so that the teeth can mesh.

As soon as the engine starts running, the flywheel drives the small pinion faster than the motor armature and threaded sleeve can revolve. With the pinion running faster than the threaded sleeve, it runs along the threads in the opposition direction from that at first, when the motor turned faster than the pinion. This sends the pinion back out of mesh, and when it reaches the end of the threaded sleeve it strikes a stop and the weight binds the pinion on the sleeve so it cannot again go into mesh.

DOUBLE REDUCTION SYSTEMS

With the pinion and sleeve mounted directly on the extension of the armature shaft there is but the single reduction of speed between motor and flywheel. In some cases a double reduction is used with a Bendix drive as shown in Figure 192, where a small pinion on the motor's armature shaft drives a gear that carries the Bendix shaft.

A Delco double reduction system that also gives different drive ratios for generating and for cranking with a motor-generator is shown in Figure 193. An extension from the pump shaft connects to the gen-

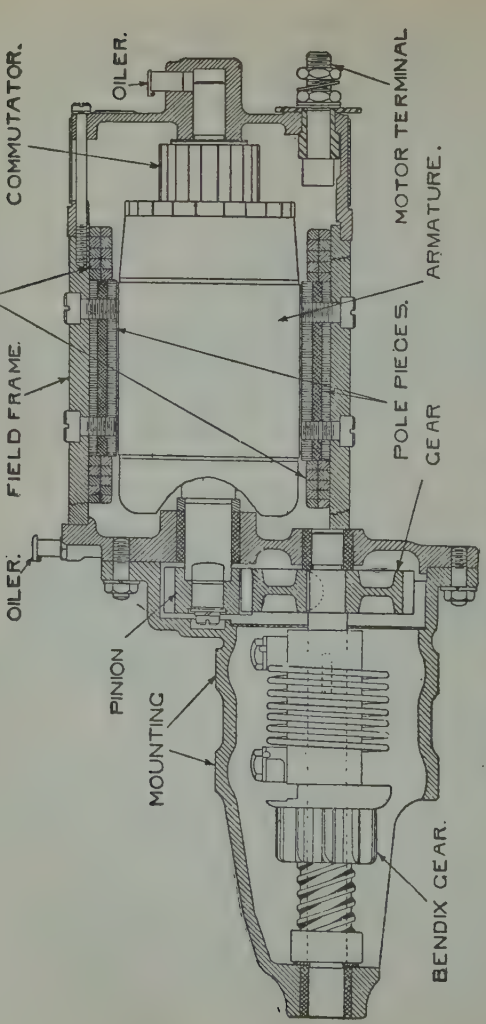


Figure 192.—Double Reduction with Bendix Drive.

erator clutch at the right end of the machine and for generating drives the armature between two and three times crankshaft speed.

The starter drive is from the rear end of the armature shaft, which carries a small pinion. There are two intermediate sliding gears that are moved by the arm operated by the starting pedal, the larger

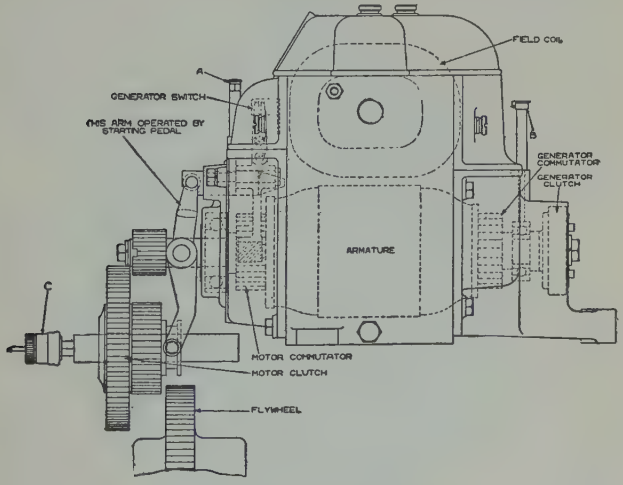


Figure 193.—Delco Two-Ratio System with Double Reduction.

gear meshing with the motor shaft pinion and the smaller one with the flywheel gear teeth. This double reduction gives the usual cranking ratio between motor and engine while starting takes place.

Overrunning Clutch.—It will be seen that in the system just described the armature shaft must run at a speed while cranking that is considerably higher than would be allowed by the generator drive from

the pump shaft. To allow the motor to run fast enough for cranking, a one-way clutch or overrunning clutch is placed between the armature shaft and the driving shaft so that the drive shaft can run the armature but so that the armature cannot run the drive shaft.

It will also be realized that with any drive system that does not automatically disengage the gears, the instant the engine starts to run, the motor armature shaft would be driven at an exceedingly high and dangerous speed by the engine's power. To prevent this, an overrunning clutch is placed in one of the gears between the flywheel and armature shaft. The action of such a clutch is shown in Figure 194.

The armature shaft is represented by the pinion *C* which drives the outer part *A* of the clutch in the direction shown by the arrow. The inner part of the clutch carries several rollers *R* forced into the wedge-shaped slots by small springs *S* and plungers *P*. Rotation of the outer ring in the direction of the arrow wedges the rollers tightly between the outer and inner parts, and the inner one *D* is driven by the outer so that the motor's power is applied to the flywheel.

As soon as the engine starts, the inner part is driven in the same direction by the engine, but at a greatly increased speed, this action rolling the rollers back into the wider part of the slot so that there is no longer any binding between the rings and the engine runs freely without driving the motor.

The gears are then taken out of mesh because continued high speed rotation of the inner part of the clutch with the outer part standing still would overheat the device and burn out the lubricant.

Acting as a generator clutch, the driving shaft would be attached to the outer ring *A* and the arma-

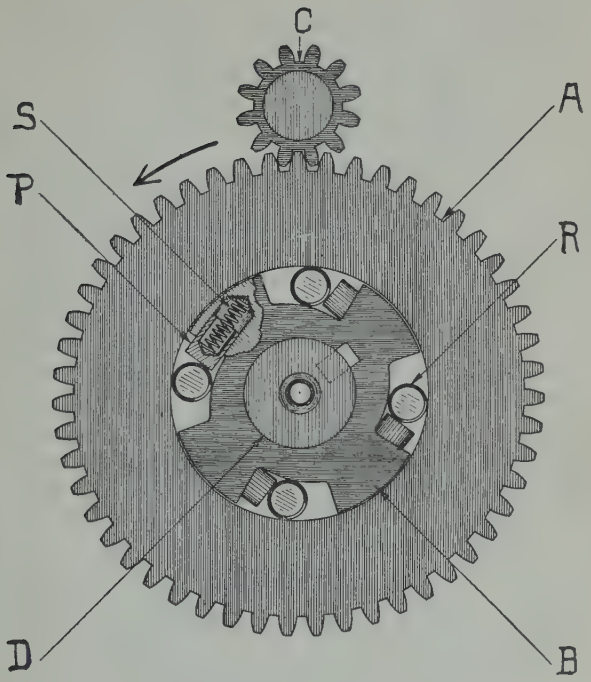


Figure 194.—Overrunning Clutch. A—Driving Ring. B—Driven Ring. C—Driving Pinion. D—Driven Shaft. P—Plunger. R—Roller. S—Plunger Spring.

ture attached to the inner part *D*, thus allowing the armature to run faster than the pump shaft while cranking takes place.

MAGNETIC PINION SHIFTS

Several methods of meshing the starting pinion by magnetic action have been used. In some cases extra electromagnets are employed to shift the gears and to operate the switches, in others the armature and fields perform the shifting.

Westinghouse Magnetic Gear Shifts.—In addition to a mechanically operated system and other application using the Bendix screw, Westinghouse equipment has been furnished with gear-shifting devices and starting switches operated by powerful plunger magnets or solenoids (Figure 195). Passing through the starting motor armature shaft is a sliding rod which carries the spur pinion for flywheel meshing at one end and the core of a solenoid winding at the other. This rod is free to slide endwise, but must turn with the armature shaft. In series with the starting motor circuit is the winding of the solenoid, and when the current for the starting motor passes through the winding the core is pulled back, with the result that the spur pinion, which has helically cut teeth, is meshed with the flywheel gearing. The gears are normally held out of mesh by a coiled spring, and when the pull necessary to start the engine is no longer required, the solenoid is demagnetized to such an extent that this spring pulls the gears out of mesh.

A Westinghouse electromagnetic pinion shift without the magnetic starting switch is shown in Figure 196. Closing the starting switch sends current through the motor so that gear meshing, cranking, and unmeshing take place just as with Figure 195.

Rushmore Gear Shift.—With Rushmore and some of the Bosch systems the starting motor armature is held out of line with the pole pieces by a long coiled

spring as at *1* in Figure 197. The pinion *P* on the end of the armature shaft is then out of mesh with the flywheel gear *F*. Applying battery current to the

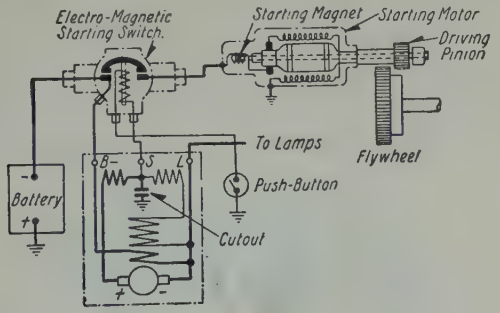


Figure 195.—Westinghouse Magnetic Pinion Shift with Electro-magnetic Starting Switch.

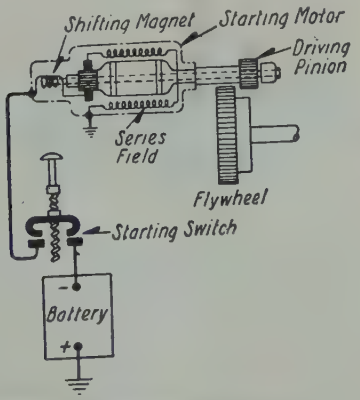


Figure 196.—Westinghouse Magnetic Pinion Shift.

starting motor draws the armature into the field, which draws the pinion into mesh with the flywheel, and cranking takes place.

The starting switch is built as shown in Figure 198. On the first contact, in the upper drawing, all of the battery current flows through the fields so that they are strongly magnetized to draw the armature and pinion into position. In this position the battery current is held low in value because of flowing through the resistance shown on the lower part of the switch. The armature current is low because of the by-pass through which most of the current

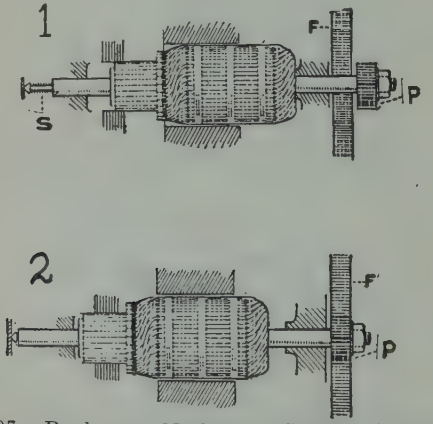


Figure 197.—Rushmore Method of Starter Gear Meshing.

flows around the armature. In the second position, after the pinion has meshed, the by-pass is cut out and the resistance is short circuited.

When the engine starts, it drives the motor fast enough to cause it to momentarily become a generator, opposing the battery current. As the battery current is thus stopped, the coiled spring throws the armature endwise and takes the pinion out of mesh with the flywheel.

OTHER DRIVE METHODS

In Figure 199 is shown a drive and starting switch once commonly employed. The rod R is attached to the starting pedal and carries the sleeve Y which slides the pinion P along the armature shaft D into mesh with the flywheel teeth F. With the teeth engaged, the starting switch contacts A are brought together and cranking takes place. Should the teeth

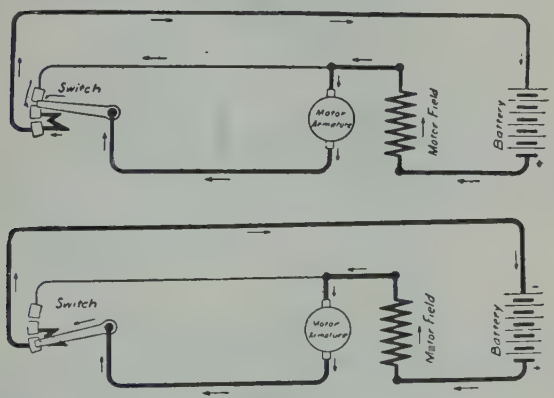


Figure 198.—Circuits of Rushmore Starting System.

meet end-on and fail to mesh, the rod R slides through sleeve Y and compresses the spring S. This movement of the rod closes the switch and the pinion is turned by the motor so that the pinion is snapped into mesh with the flywheel teeth by the tension of the compressed spring.

At the top of Figure 200 is shown a Bijur system with which butting of the teeth of pinion and flywheel allows the shifting rod to compress the shifter spring and close the starting switch. This causes the motor

to turn the pinion and the compressed spring forces the gears together.

Still another method of allowing gear meshing is shown in Figure 200 at the bottom. The starting

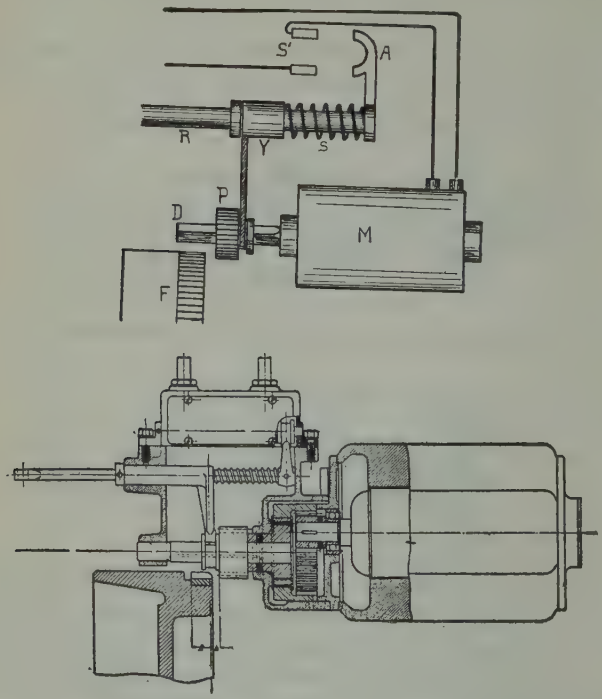


Figure 199.—Spring Shift for Starter Pinion. (Auto-Lite)

switch now has two pairs of contacts, P and P^1, and Q. Between the contacts P and Q is a resistance R. The pinion is normally held out of mesh with the flywheel teeth and in the position shown. When the starting

switch button is pressed down, the pinion is moved toward the flywheel, but before the teeth are in a meshing position the starting switch contacts P and P^1 are connected by the moving contact piece on the

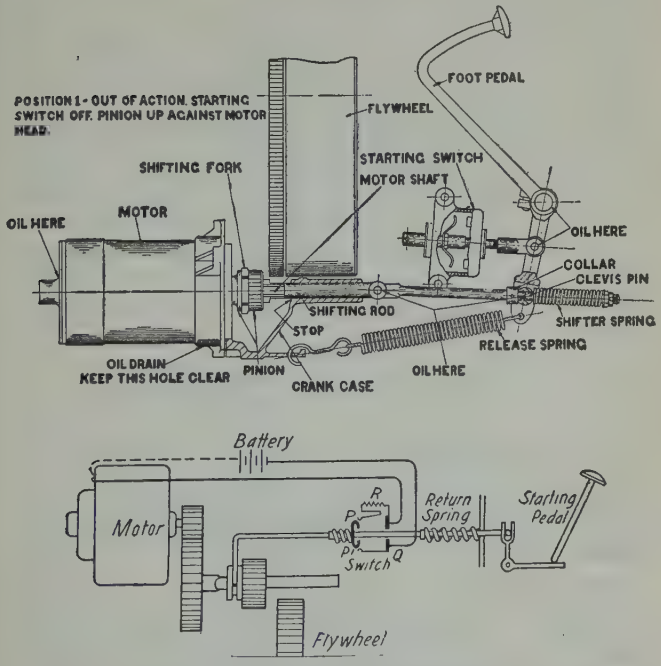


Figure 200.—Top: Bijur Spring Pinion Shift. Bottom: Westinghouse Resistance Starting Switch.

switch rod. Battery current then flows through the motor and to the switch contact through the resistance, which reduces the flow of current, and by way of the contact P, contact piece and contact P^1, to the

wire and back into the battery. The armature shaft and pinion are thus revolved at high speed with little power, and as the switch rod continues to move the pinion toward the flywheel, the contact piece in the switch leaves the contacts P and P^1, so that the pinion is left spinning but without any current passing through the motor. The revolving pinion slides into mesh with the flywheel teeth, and by the time the gears are fully meshed, the contact piece in the switch has come against the main contacts Q, thus closing the circuit between the battery and motor without the resistance, so that the fully battery voltage is used for cranking. An overrunning clutch is carried in the starting motor housing or in one of the intermediate gears.

REVIEW OF CHAPTER VII

THE STARTING SYSTEM

The **amperage through a starting motor** increases with decrease of armature speed and increase of torque.

The **efficiency of a motor** is the ratio of the power delivered by the motor to the power in watts consumed by the motor in running.

One horsepower is the amount of work done in raising 33,000 pounds one foot high in one minute. The horsepower is found by multiplying the number of pounds, by the distance in feet through which it is lifted, by the time in minutes, and dividing the product by 33,000.

The **horsepower and efficiency of a motor** rise to their maximum at medium speeds, then both fall off at higher speeds.

Starting switch action is secured with some Delco systems by raising and lowering one or more of the **starting brushes** on their commutator.

Magnetic starting switches are operated by a solenoid or plunger magnet around whose windings the starting current passes.

Switches for some of the older **motor-generators** are closed for starting and allowed to remain closed to carry the charging current as the machine changes to a generator.

Commutating switches are used with systems charging at one voltage and cranking at a higher voltage.

With the **Bendix drive**, rotation of the threaded sleeve by the motor screws the pinion into mesh with the flywheel gear; the spring then coils tightly, and the motor's power applied through the spring cranks the engine. Rotation of the pinion by the flywheel after the engine starts, screws the pinion back out of mesh.

An **overrunning clutch** connects two parts so that the clutch rings are wedged by the rollers to allow one part to drive the other, but so that more rapid rotation of the second part in the same direction releases the rollers and disconnects the drive.

Magnetic pinion shifts move the motor pinion shaft by the action of a plunger magnet through whose winding the starting current passes. Rushmore systems allow the magnetism between fields and armature to draw the armature and pinion shaft endwise.

Spring operated starting switches are used to allow closing of the switch before the starter gears are in full mesh, the gears then being meshed by the tension of the compressed spring.

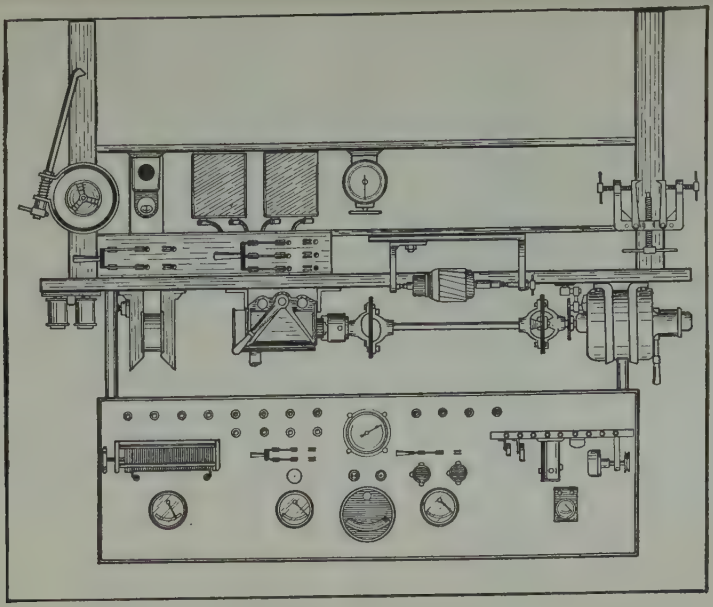


Figure 201-A.—Test Bench for Generator, Motor, Ignition and Battery Work.

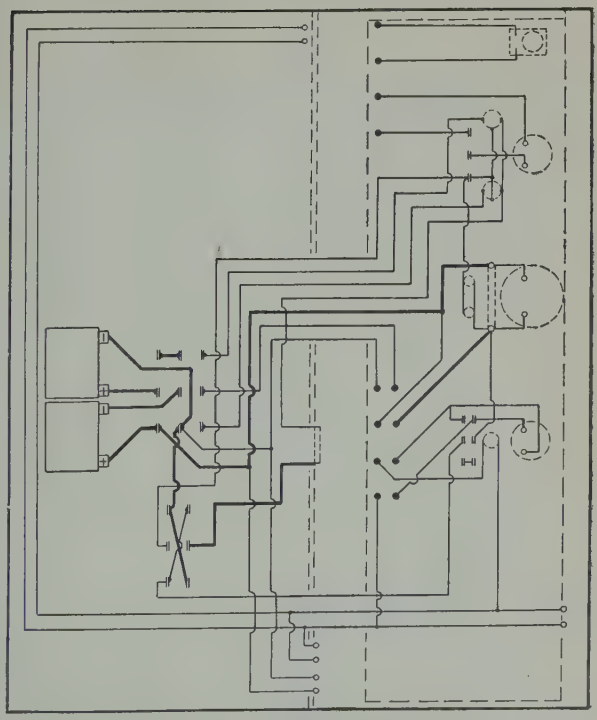


Figure 201-B.—Wiring of Test Bench for Generator, Motor and Ignition Work.

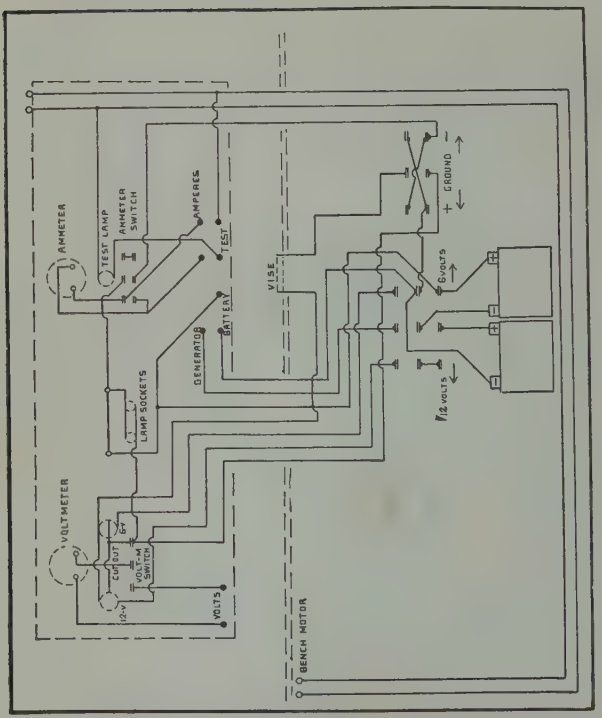


Figure 201-C.—Wiring of Test Bench for Generator and General Work.

CHAPTER VIII

UPKEEP AND CARE

The greatest difficulty of those making electrical repairs is in realizing the requirements of the electric circuit. The electric circuit is defined as "the path in which electricity circulates or passes from a given point, around and through a conducting path, back again to its starting point." It is in tracing

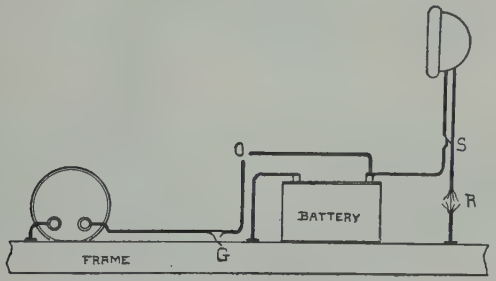


Figure 202.—Common Troubles in Wiring (Charging and Lighting System). G—Accidental Ground. O—Open Circuit. R—High Resistance. S—Short Circuit.

the circuit all the way around and back to its starting point that the difficulty occurs. It is not enough for the current to flow from the generator or battery to the different units in the electric system, but it must also return again to the generator or battery.

The experienced electrical man starts from the source, follows the conductors to the first device in the circuit, makes sure that all the current flows

through this device, and finally traces the current path back to the source.

The majority of electrical troubles come under one of four heads: (1) open circuits, (2) circuits with abnormally high resistance, (3) short circuits, and (4) the kind of short circuit called a ground. These are shown for a generating system in Figure 202 and for a magneto ignition system in Figure 203.

Open Circuits and High Resistance.—With an open circuit the current path is not complete from the

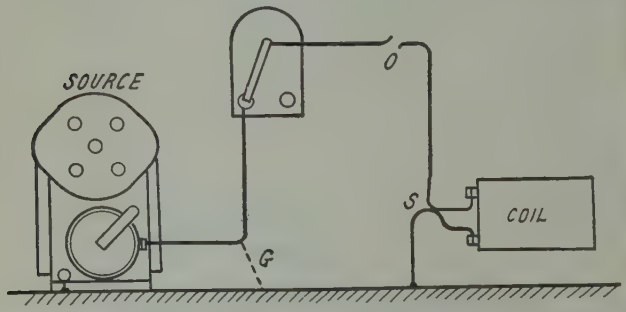


Figure 203.—Wiring Troubles (Ignition System). G—Ground. O—Open Circuit. S—Short Circuit.

source through the current consuming devices and back to the source, and no current flows in any part of the circuit. With high resistance the circuit is complete, but the resistance is so great at some point as to prevent the flow of enough amperage to do the work. Some causes for these troubles are as follows:

Open Circuit—
- Wire broken and hanging loose.
- Wire broken inside of insulating cover.
- Wire disconnected at terminal.

High Resistance—
Wire of too small gauge size.
Wires partly broken through.
Wire of too great length for voltage of system.
Open Circuit or High Resistance—
Terminal fastenings dirty or loose.
Poorly made joints between wires.
Wrong connections.
Dirty or pitted contact points.

Short Circuits and Grounds.—With a short circuit the current from the positive of the source returns to the negative side without having passed through all of the conductors and current consuming devices in the circuit. An accidental ground is a short circuit in which the current leaks back to the source through the metal of the car parts. Common causes for either of these two classes of trouble are as follows:

Wires wet, oily or dirty.
Insulation broken or worn from wires.
Dirt, oil, or moisture at terminal connections.
Loose wire strands at terminal connections.
Wrong connections of wires.

LOCATION OF TROUBLES

Ammeters, voltmeters and circuit testers are used for the location of opens, high resistance, shorts and grounds. Ammeters and voltmeters are much alike in construction, the difference being that the voltmeter's resistance is very high, so that only the pressure in the circuit is indicated, while the ammeter carries all of the current flowing in the circuit through a very low resistance formed by a part of the instrument called its shunt, to the ends of which are connected

the meter movement and the terminals for the circuit connections. An ammeter with an inside shunt is shown at *A* in Figure 204 and one with an external shunt at *B*. The circuit whose amperage is to be measured is completed through *X* and *Y*.

Use of the Voltmeter.—The high resistance of a voltmeter is an advantage in circuit testing because it prevents too much current from passing through a circuit. The low resistance of an ammeter, when connected to a battery circuit, for example, might allow

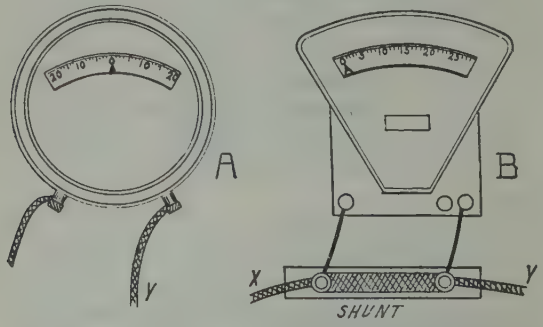


Figure 204.—Meter Connections. A—Ammeter with Self-Contained Shunt. B—Meter with External Shunt.

a flow great enough to burn out the meter in case a short or ground existed.

Open circuits or high resistances are located with a voltmeter as in Figure 205. At *A* the circuit from one side of the battery to the other is complete, and with the voltmeter connected as shown there will be a very low voltage reading, since only the voltage drop through the conductors is measured. Should the circuit be open as at *B* the meter will indicate full battery voltage, while with a high resistance it will

indicate a voltage in proportion to the resistance of the circuit.

Location of shorts and grounds with a voltmeter is shown in Figure 206. The meter is connected in series

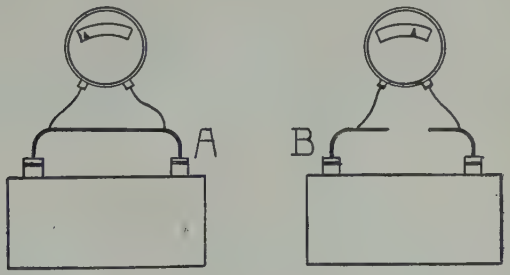


Figure 205.—Open Circuit Test with a Voltmeter.

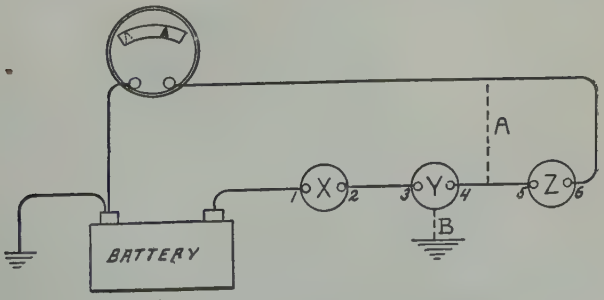


Figure 206.—Test for Grounds and Short Circuits with Voltmeter in Series.

with the circuit and all switches are turned off. Any voltage reading shows that it would still be possible for current to flow with the switches open and either a short exist as at *A* or a ground as as *B*. With these troubles removed the voltmeter will show no reading.

To locate the point of trouble, connections are removed from terminals in the circuit. If current is flowing through the short at *A*, removal of the wires at *5* or *6* will not stop it and the meter will still show a reading. But removal at *4* will stop the leak and the meter will read zero. The trouble always exists between the point from which removal of a wire stops the reading and the last point that did not stop it. If part *Y* had been grounded at *B*, then the trouble

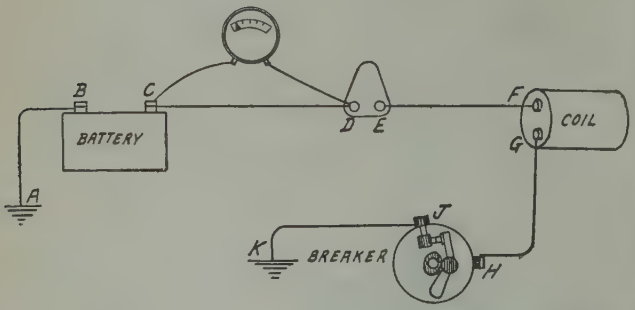


Figure 207.—Test for Open Circuits and High Resistances with Voltmeter in Parallel.

would not be stopped until connection *3* was opened, showing it was between *3* and *4*, or in part *Y*. In making this test the meter should be attached near the battery and the work of opening the terminal connections should proceed away from the meter as shown.

The use of a voltmeter in locating open circuits or high resistances is shown in Figure 207, for which the principle is the same as in Figure 205. With switches closed the meter is connected across various parts; for example, at *C* and *D*. A very low read-

ing across a conductor or unit in the circuit shows that no trouble exists, but a high reading shows too much resistance, while full voltage shows an open.

To test the ground connection, the meter would be connected between *A* and *B*, the switch would be tested between *D* and *E*, the coil between *F* and *G*, and so on for all parts. The switches should be closed, any ignition breaker should have its contacts together, and the current path should be normally complete for

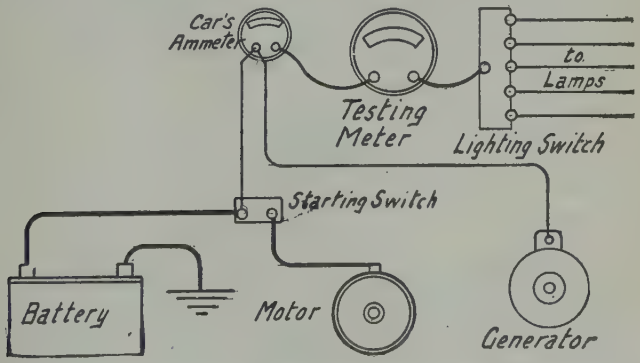


Figure 208.—Test of Lighting Circuit with Voltmeter.

this kind of a test so that current may flow to the meter as it is placed across the various parts. Whenever the meter shows a high voltage reading it is connected around a part or conductor having an open circuit or a high resistance.

These are the general principles for locating electrical troubles with a voltmeter and with the help of a wiring diagram applying to the equipment being handled they may be applied to any car. If it is known that trouble exists only in one circuit, the

meter may be attached at the beginning of this circuit in place of at the battery. In Figure 208 the meter is shown at the beginning of the lighting circuit when trouble is known to exist only in the lamps.

Circuit Tester.—The circuit tester shown in Figure 209 consists of two insulated leads in series with a lamp attached to any electric lamp socket. If these tester points are touched to two points of the electric system and the lamp lights, it will show that there is a circuit path between the points; while if the lamp does not light, there is no circuit between them.

Before testing for accidental grounds it will be

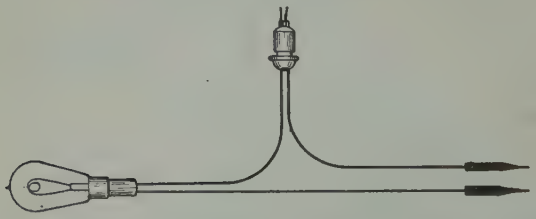


Figure 209.—High Voltage Circuit Tester on Drop Cord.

necessary to remove all normal grounds. If one side of the battery is grounded it must be disconnected; grounded lamps should have their bulbs removed or their connectors removed; grounded horns, coils, etc., should be disconnected or their grounded side disconnected. Then, with one tester point on the metal of the car and the other on the wire remaining attached to the battery, an accidental ground will be indicated by the lamp's lighting. Any wire or any unit may thus be tested by disconnecting it at its terminals and, with one side of the tester touching the metal work, touching the other side to the suspected

wire or part. If the lamp lights it indicates a ground.

To test for short circuits between two wires or parts it is only necessary to touch one test point to one of the wires or parts and the other test point to the other wire or part. Lighting of the tester lamp indicates a short circuit between them.

If it is thought that a wire or part is broken, it may be tested by placing one test point on each end of the wire or part. If the lamp lights it indicates a complete circuit, while if it fails to light it indicates a break.

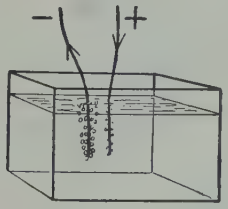


Figure 210.—Polarity test for Conductors.

Open circuits or high resistance may be located in any suspected parts, such as switches, by making a temporary connection around them with a length of wire having its ends clean and bright. If this wire, bridging around the part or conductor thought to be defective, allows normal operation, it indicates that an open circuit or high resistance exists between the points joined by the test wire.

Polarity Test.—The polarity of any wire or terminal may be determined by attaching leads to the two sides of the circuit being tested and placing their ends in water to which has been added a little salt or acid as shown in Figure 210. The wire on the negative

side will give many more bubbles than that on the positive when their ends are separated a little distance.

A voltmeter having one terminal marked positive, when connected with this terminal attached to the positive side of a circuit, will show a reading; while if the negative side of the circuit is attached to the positive of the meter, the pointer will tend to move backward and will show no reading.

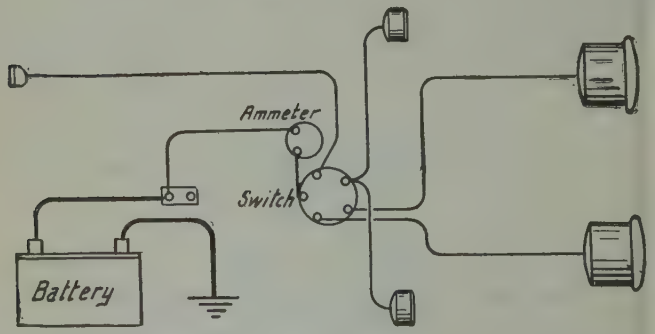


Figure 211.—The Lighting System.

LIGHTING SYSTEM TROUBLES

The light from the bulbs is directed toward the road by means of silver plated reflectors of parabolic shape. These reflectors are protected by glass doors which may be opened for bulb focusing or cleaning of the reflectors.

The lamp door may be held by hinges or with a pin joint on each side, from one of which the pin may be withdrawn to let the other side act as a hinge. A type of lamp that is in the most common use holds the door by means of a spring lock, and with the door

in position nothing about the outside of the lamp gives any indication as to the method of fastening. This type is handled by pressing in on the rim of the cover and at the same time turning it to the left, when the whole front of the lamp will come off. Great care should be used to prevent dirt or moisture from touching the reflector while the cover is removed.

Should the reflectors become dirty or tarnished, they may be carefully cleaned and brightened, although the surface of the reflector will be somewhat

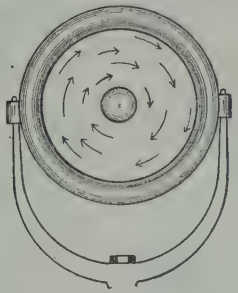


Figure 212.—Method of Cleaning Lamp Reflectors.

damaged every time it is touched, no matter how careful the work is done. Dust may be removed from the reflectors by blowing it out or, if it does not yield to this treatment, a stream of clean cold water at very low pressure may be used. If water is used the reflectors must be allowed to dry by the air alone, and must not be wiped off.

For cleaning the silvered surface no liquid except alcohol is ever used. This is applied with a clean, soft chamois skin. The chamois must be held so that there are no wrinkles, and the reflector is then wiped over the whole surface by using a rotary motion (Figure 212), starting at the bulb socket and

gradually working out toward the front of the lamp. The cleaning is sometimes done by wiping from front to back, but in either case the pressure should be very light and even. Rubbing back and forth will surely scratch the surface of the reflector.

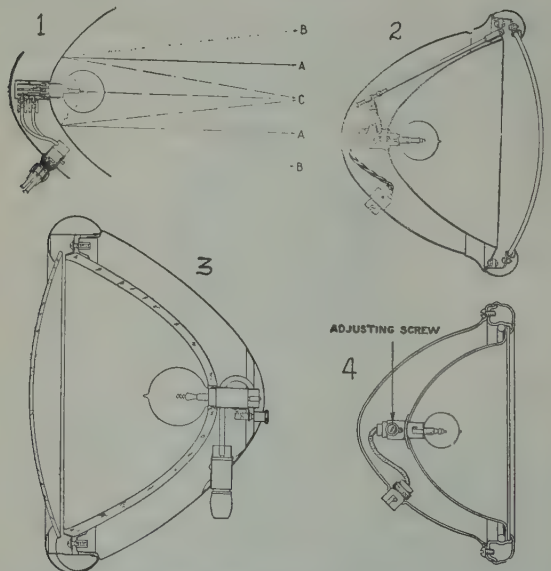


Figure 213.—Lamp Focusing Methods. 1—Light Rays Follow Lines *A* with Proper Focus; with Improper Adjustment They Follow Lines *B* or *C*. 2—Focusing Screw at Upper Front Edge of Reflector. 3—Focusing Screw at Rear of Lamp Case. 4—Adjusting Screw in Lamp Socket.

If the silvered surface is tarnished it may be polished by moistening the chamois with alcohol and then applying a small quantity of jeweler's rouge. The wiping should then be done in the same way as for cleaning. After the coating of oxide has been re-

moved, the polishing is completed with more rouge placed on a dry chamois skin.

The bulbs are first focused and then the lamps are turned on their brackets or the brackets bent to direct the light onto the road. Focusing is done by moving the bulbs forward or back so that their filaments will come into a different relation to the curved surface of the reflector as at *1* in Figure 213. Some lamps are made so that the bulb position may be changed by turning a small screwhead or nut exposed when the lamp door is opened as at *2*. Bulbs are also held in a socket that slides after it is turned slightly

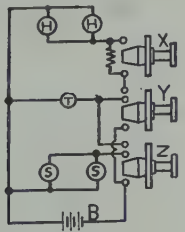


Figure 214.—Resistance Dimming.

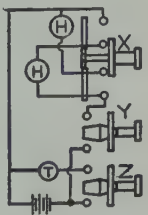


Figure 215.—Series-Parallel.

or after a holding spring is pressed. Other lamps have an outside focusing screw as shown at *3*, while with still others there is a screw holding the socket in place in the reflector as at *4*, which is reached with the reflector removed.

One lamp should be focused at a time. This may be done by turning the current off from one of them or by covering one with a thick cloth or coat. The focusing must be done in a dark room or on a dark road, preferably on the road. The car should be placed so that no street lights are near enough to cast a light near the car, because they will affect the

adjustment. The bulb should be moved back and forth until the light on the road is clean and free from rings or black spots. If the work is done in a room, the light may be directed against a wall and the bulb moved until a clean and clear ring of light is thrown straight ahead. It will always be best to drive the car on the road before deciding that the adjustments are correct. It will often be found that focusing which is apparently right with the car standing still will not be the best that may be secured for driving.

The subject of lamp focusing is closely related to

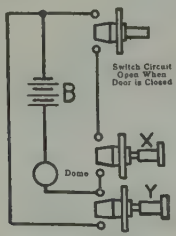


Figure 216.—Dome Lamp Switch.

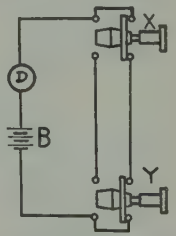


Figure 217.—Parallel Switches.

that of lamp dimming, which is treated in Chapter VI on Lamps and Wiring. The matter dealing with the position of the light rays as they strike the road surface and as they strike the surface of a vertical wall should be noted, since these positions are determined both by the focusing of the bulbs in their reflectors and by the setting of the lamps on their brackets or the setting of the brackets on the car.

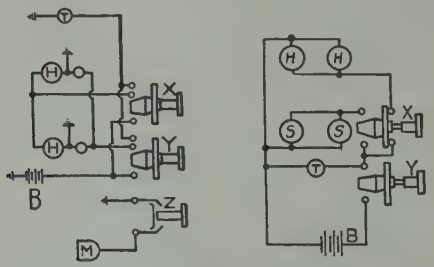
In case of failure to light, the bulbs themselves should be examined to make sure that they are not broken and that the filaments are not burned out. Should the lamp have been fitted with bulbs designed

for a voltage lower than that used on the car, the filaments will be burned out, while bulbs designed for a higher voltage than that used will not light at all. The average life of a good tungsten filament bulb should be from 100 to 300 hours, but low-efficiency or cheap bulbs may become dim or may burn out in much less time.

It is quite possible for dirt, loose wire strands or faulty construction to cause an accidental short-circuit in the bulb base or in the socket into which the base fits. Such a fault will probably result in allowing such a heavy flow of current at the defective point that heating will result, and at the same time all the other lamps on that circuit or line will burn dimly or not at all. It may be found that the small contact points on the bottom of the bulb base do not make contact with the plungers or springs in the socket. The springs may be bent up slightly or the contact points may be extended by the addition of a drop of solder to each. If the socket contains spring plungers, they should be pressed down and examined for binding or dirt that will cause sticking when the bulb base is pressed home. If the plungers can be pressed down and then remain down, it indicates that the springs have become broken or are binding, and a new socket is the most satisfactory remedy. The interior of the bulb sockets should be kept free from dirt and foreign matter of all kinds because the result may be either a short-circuit or an open circuit for that particular lamp. It is customary to provide the lamps with connectors into which the wires fasten and which complete the circuit by means of plungers or pins that fit into holes in a second part of the connector. The same remarks respecting dirt and

poor connections apply to these outside connectors as to the bulb sockets. Should the lamps flicker and occasionally go out altogether, the wiring at the sockets and at the connectors should be examined for loose strands. In case a part of the copper is found exposed, it should be wrapped with insulating tape to prevent a repetition of the trouble caused by the movement and jarring of the car while in motion.

The points at which the wires turn around corners, and the points of fastening by means of cleats on the



Figures 218 and 219.—Combination Controls for Lamps.

metal work, should be given a careful inspection, and the conductors should be moved wherever possible while the lamp switches are turned on to test for broken wires underneath the insulation.

In case it is necessary to run lines through places where they will become wet or oily, the wiring should be enclosed in metal conduits or by circular loom, and the openings through which the wires enter and leave the cover should be taped.

In the case of a car equipped with fuses in the lighting or charging lines, they should be examined and

should a fuse be found burned out, the line leading away from it should be examined for the short circuit that is almost sure to be found. It will do no good to replace a fuse in a lighting circuit until the cause of its burning out is found and remedied, because a new fuse will only suffer in the same way as the old one as soon as the faulty conditions reappear. Fuses should never be replaced with others of a higher capacity than those originally furnished with the car, because the protection to the circuits and other units will no longer be present. The final result of such replacement will probably be damage many times more serious and more costly than the new fuse of the proper size would have been. Such advice applies even in stronger measure to replacement of fuses with lengths of copper wire. This is the poorest kind of economy and should never be practiced. It will oftentimes be found that a failure to complete a circuit through a fuse is due to poor contact of the fuse with its holding clips or due to poor contact of the clips and terminals with the wire ends that are attached at these points. A minute piece of foreign matter between the fuse and the clip will prevent a flow of current, and before deciding that the fuse is burned out, it should be turned around in the clips once or twice to remove any such particles. The clip ends should be pressed together until they hold the fuse firmly, and the screws that hold the wire terminals should be turned down tight.

The contact points of circuit breakers should give no trouble because they are so seldom called upon to do any work. In case of high resistance or an open circuit in lines protected by these devices it can do no harm to examine them and to clean the contacts

by drawing strips of very fine emery cloth between them while held closed. The spring tension should never be changed to overcome trouble.

Lighting switch contacts should be examined for bending, binding, looseness, dirt, or corrosion; also to make sure the moving parts are not loose and that the terminal studs are tight.

Various arrangements of lighting circuits are shown in Figures 214 to 219. In Figure 214 button *X* makes the head lights dim or bright after they are turned on by button *Y*. Button *Z* lights the side and tail lamps. In Figure 215 is shown a series-parallel dimming arrangement. Button *Y* turns the head lights on and off. With them turned on, and button *X* in, they are dimmed in series, while with *X* out they are bright in parallel.

Figure 216 shows a door switch (upper one) for the dome light. With *X* closed the dome lamp is controlled either by the door switch or by switch *Y* without the door switch. Figure 217 shows a dome light control so that the lamp may be either lighted or put out with either switch operated alone.

In Figure 218 button *X* lights the large head lamps and the tail lamp, *Y* lights the small bulbs and tail lamp, while *Z* controls the magneto. In Figure 219 *Y* controls all the lamps, *X* the head and tail lamps, and *Y* the side and tail with *X* open.

CHARGING SYSTEM TROUBLES

Any failure of the dynamo, cut-out, regulating device or charging wiring will result in the specific gravity of the battery electrolyte becoming abnormally low, and in the voltage of the battery falling below two for each cell. As far as the wiring is concerned,

the same advice as that given for the lighting circuits may be applied to this case. Other troubles may come from faulty conditions of the dynamo brushes, commutator, armature or fields, or from faults in the cut-out and regulator.

No general conclusions can be drawn and no general rules given by which it may be determined whether or not a dynamo is giving its proper amperage. If the characteristics of the particular machine being considered are known, the work is made easy; but in the absence of this information it is generally necessary to make additional tests on other units, such as the battery. These tests will show whether the dynamo is doing its proper work provided everything else is known to be in condition for efficient use. There is but one rule that may be useful in the superficial checking of the dynamo operation; this rule being that an ammeter attached to the battery should show some charging with all lamps turned on and the engine running between fifteen and eighteen miles per hour car speed.

The rule as stated will almost always hold good, and if the ammeter should show a discharge under those conditions it is safe to assume that the dynamo is not giving sufficient output or else that some trouble exists between dynamo and battery that is preventing the proper charge from entering the battery. It is of course assumed that the lighting system and wiring is in good order while making the test.

If it is desired to test the condition of the dynamo only, the test should be made at the dynamo itself. If it is desired to test the actual charging conditions on the car, the test should be made at the battery, because it is the charge that enters the battery that is

of importance. The dynamo might be doing all that could be expected of it, but the current generated would be of no use unless it was reaching the battery, lamps, etc.

In testing the output of a dynamo, an ammeter should be inserted between one of the dynamo terminals that carries charging current and a wire end removed from this same terminal. A test made between the positive and negative terminals of the dynamo would not give the same results under ordinary conditions. With a majority of the dynamos in use, a storage battery, or its equivalent in resistance, must be in the dynamo circuit while making the test, because the output of the dynamo depends on its having to make an effort to force the current through the battery. Additional information on making such tests will be given, but the foregoing precautions should always be observed and were mentioned thus early because of the misunderstanding that so often exists.

BRUSH CARE

With the brushes exposed, their holders should be examined to see that the pivoted arms are free to swing back and forth, and that sliding brushes do not bind or wedge in any position. Such binding of the brush itself may be remedied by carefully dressing the sides with a fine file. Attached to each brush or to the brush holder is a short length of flexible wire called the brush pigtail. These small wires must not be broken and their connections must be clean and tight at each end.

Either the brush itself or else the brush holder is held by a coiled or flat spring so that the brush bears

on the commutator surface with a tension just sufficient to cause the brush end to make good contact at all armature speeds. These brush springs should not be bent, loose, broken or binding, and should have sufficient tension to cause a good firm connection to be maintained, but should not be set up so tight that there is danger of the brush cutting into the commutator surface.

In a great many dynamos the brushes or their holders are insulated from the remainder of the dynamo by means of bushings, washers and sleeves. These insulating parts must not be broken or cracked, and if covered with oil or carbon dust should be thoroughly cleaned. In the case of grounded return systems, when the ground connection is made through the pig-tail, the brush itself may be insulated.

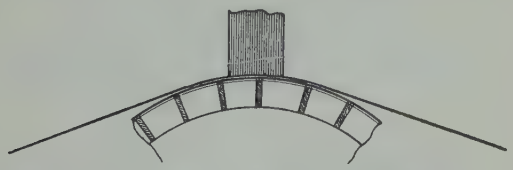


Figure 220.—Fitting Brush-End with Sandpaper or Cloth.

The electrical resistance between brush and commutator depends chiefly on how well the brush end fits the commutator surface against which it bears. High resistance lowers the efficiency of the dynamo and is the primary cause of more serious troubles. For these reasons the brush ends should always be properly fitted. This operation is performed as follows:

A strip of "000" sandpaper should be cut so that it is at least as wide as, and preferably a little wider than, the end of the brush to be handled. With the dynamo idle, the brush should be drawn away from

the surface of the commutator so that the strip of paper may be drawn between the brush end and the commutator with the sand side toward the brush, Figure 220. The paper should then be drawn back and forth under the brush end and should be held so that it follows the surface and curve of the commutator while passing under the brush. The sand will remove enough of the brush end to allow a perfect fit on the commutator surface to be secured. After all roughness and unevenness have been removed from the brush, the end should be carefully wiped with a clean soft cloth. All particles of dust should be removed from the interior of the dynamo with a cloth moistened with kerosene or by blowing them out with air. Each brush should be dressed in this way, even though only one seemed to need the treatment. Great care should be used in dressing the ends of regulating brushes and they should always be dressed after moving them to a new position. It is absolutely essential that the brush ends shall make perfect and full contact over their entire section.

The brushes are practically the only part of the dynamo that will require periodical replacement. It is not possible to state any definite time that brushes should last; this depends on the design and construction of the dynamo. They should be examined occasionally and their length noted. When it is seen that they can wear only one-eighth of an inch more before allowing their holders or springs to touch the commutator, they should be removed and replaced with new ones. A brush should be expected to wear at least a year, although this time may be affected by many conditions. New brushes should always be fitted to the commutator surface by the method described above.

The brush should be free to move at all times. If fastened securely to the holder, the holder should be free to move on the pivot that supports it, and if any binding is present, the dynamo output will be affected. If the brush slides in the holder, care must be used to see that the sides of the brush do not bind under any conditions. Should binding be found at this point, the sides should be dressed to a fit.

The brushes are held against the commutator surface by means of springs of various forms and types.

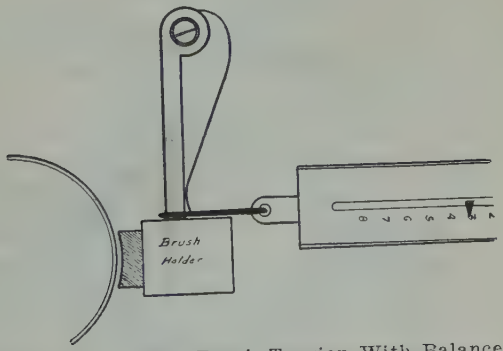


Figure 221.—Testing Brush Tension With Balance.

The tension of these springs is usually adjustable by some means, either by moving one end of the spring from notch to notch of an adjustment segment, by tightening or loosening a holding screw or by some other easily discovered means. The tension on brushes varies from an ounce or two up to nearly two pounds, depending on the design and requirements. In all cases the tension should be sufficient to maintain a good running contact, that is, so that the dynamo output will not be impaired and so that spark-

ing will not take place with other factors taken care of. The tension should be as low as is possible and still secure good contact. More than this will cause excessive wear and overheating. See Figure 221.

Commutator Care

In order that the brushes may make a good contact

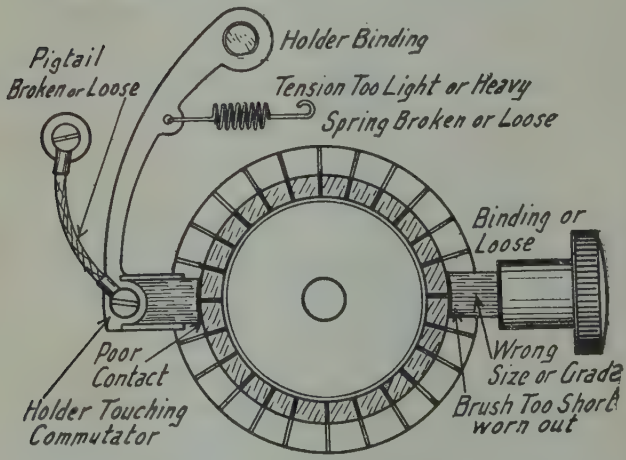


Figure 222.—Brush Troubles.

with the copper bars of the commutator, they must be maintained in proper condition. That means that the commutator surface must be smooth and perfectly cylindrical. Should the surface become dirty, scratched, rough or pitted it must be restored to good condition at once if the dynamo is to be maintained in good condition.

The commutator surface should be of a rather dark brown color and should have a slightly glazed appearance when in the best condition. Should an examination show it to be blackened or dirty it may be cleaned by holding a soft cloth slightly moistened with gasoline against the commutator surface while the dynamo is being driven by the engine at the slowest possible speed. Oil should never be used on the surface of a commutator, but lubrication may be provided by plac-

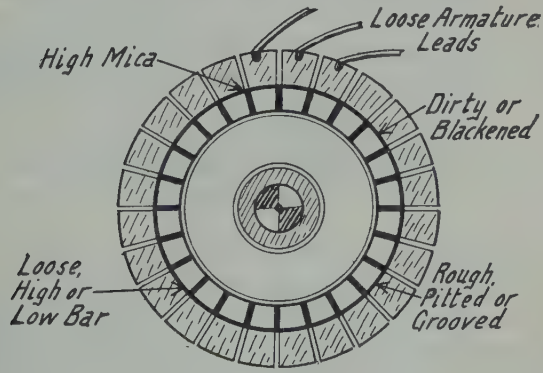


Figure 223.—Commutator Troubles.

ing a small quantity of vaseline on a piece of soft cloth or leather and holding it against the commutator surface with the dynamo revolving. Even this lubrication should not be used unless the commutator surface shows signs of scratching after being cleaned. In many makes of dynamos the brushes are made from a composition that provides sufficient graphite to lubricate the commutator surface.

If the surface of the commutator is rough or slightly scratched and pitted it may be dressed smooth with

sandpaper. Emery cloth or emery paper should never be used because emery is an electrical conductor and will short circuit the commutator bars. Before using the sandpaper the commutator should be cleaned as described. After the cleaning has been completed by washing it with kerosene the brushes should be so supported that they do not touch the commutator surface. The engine should be run at the lowest possible speed so that the commutator is revolved. A strip of "000" sandpaper should then be cut just as wide as the commutator surface, no narrower under any circumstances, and this strip of paper should be placed over the end of a thin stick of equal width. By holding this paper against the surface of the revolving commutator slight scratches or pitting may be removed. Care should be used to bear evenly on the whole width of the commutator so that grooves may be avoided.

After the surface is even and bright, the engine should be stopped and every trace of copper dust and sand should be removed from the interior of the dynamo, either by wiping out with a cloth moistened with kerosene or by blowing out with air under pressure. The insulation spaces between the commutator segments should be wiped free of any dirt or copper dust by using a soft pointed stick. The job should be completed by dressing the ends of the brushes as described in a preceding paragraph.

Should the commutator surface show deep grooves or severe pitting it will be necessary to remove the armature from the dynamo, place it in a lathe and take the thinnest possible cut from the surface of the commutator. The comparatively slight thickness of the commutator bars should be borne in mind and

no more metal should be removed than is absolutely necessary to obtain a smooth surface.

After turning a commutator in the lathe it will be necessary to "undercut" the insulation between the segments. It will also be necessary to perform this operation should the insulation be found even with or slightly above the surface of the copper bars at each side. To undercut the insulation means to remove sufficient material from the exposed edge so that its surface is about 1/32 inch below the surface of the copper bars.

The removal of the insulating material may be effected by using a very thin hack saw blade and exer-

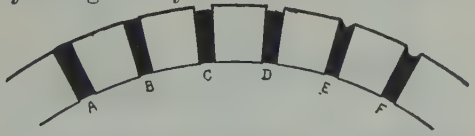


Figure 224.—Undercutting Insulation Between Commutator Segments.

cising great care to avoid bridging from segment to segment with fine particles of copper. Figure 224 shows a partial section through a series of commutator bars, the white spaces representing the copper segments and the black portions the insulating material. At *A* and *B* are shown pieces of insulation that require undercutting. At *C* and *D* are shown sections when the work has been properly done and at *E* and *F* when improperly done. When the insulation is removed it must be taken out so that the surface is flat and the corners made with the copper segments are square. A knife file should be used following the hack-saw blade so that the corners may be cleaned out. If the surface of the insulation is left grooved the work will be practically valueless.

The method used in undercutting commutator mica with a power driven cutter, mounted either on the shaft of a small motor or at the end of a flexible shaft, is shown in Figure 225.

Sparking at the brushes may be caused by a com-

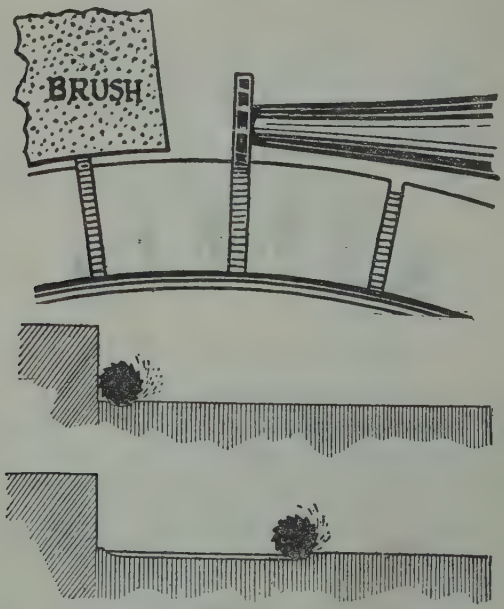


Figure 225.—Power Driven Mica Undercutter.

mutator that is rough, pitted, or dirty; by poor brush contact due to improper fitting, looseness, binding, or wrong spring tension. The brushes may be of the wrong size or grade, or it is possible that they are in the wrong position. Often the sparking is caused by high or flush commutator mica. An open cir-

cuited or short circuited armature will sometimes cause sparking at the brushes.

The common commutator troubles are shown in Figure 223. Loose or low segments will require a new commutator in most cases. The soldering of the armature leads to the commutator bars should be looked at to see that excessive heat has not melted the solder and allowed it to be thrown out. The wires from the commutator to the armature windings should be unbroken and well insulated. Worn or broken insulation should be replaced and varnished.

The armature coils may contain grounds, short

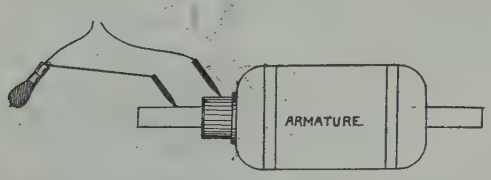


Figure 226.—Ground Test for Armature and Commutator.

circuits, open circuits, or high resistance. The test for a ground is made by placing one point of a circuit tester on the armature shaft and the other on the commutator as in Figure 226. The lamp should remain out, but if it lights a ground is indicated.

The armature is tested for an open circuit or high resistance as shown in Figure 227. With the outside connections and the field connection removed from the brushes, a single dry cell is connected as shown. With a voltmeter that reads not higher than three or four volts, a test is made of the voltage between each adjacent pair of commutator segments. Low readings or no readings at all will be obtained between all the segments except the two between which

is connected an open circuited or high resistance armature coil. Between these two segments there will be a reading of 1½ volts or nearly this amount on the voltmeter.

The test for short circuited armature coils is best made with a "growler" as shown in Figure 228. The growler is really a transformer with an open core, between the open ends of which the armature is

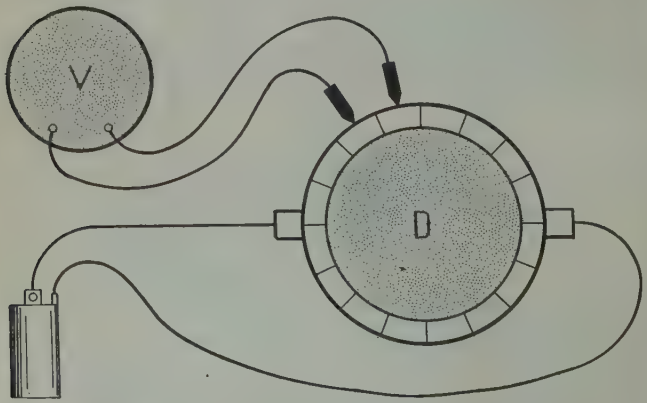


Figure 227.—Open Circuit or High Resistance Test on Armature.

placed as shown. The coil around the lower part of the growler core is supplied with alternating current from a lighting or power circuit connected to the switch. When the alternating current is turned on, the magnetism passes through the growler core and through the core of the armature being tested. If there are no short circuits in the armature windings they will act like a transformer secondary winding with an open circuit. But if there is a short cir-

cuit, the current induced in the armature windings by the growler magnetism will cause a heavy current to flow in the armature windings and the core will be strongly magnetized at the shorted coil.

The armature is first placed between the poles of the growler and then the alternating current is turned on. A short length of hack saw blade is held a fraction of an inch above the armature core and in line with the armature shaft. The armature is turned around slowly, keeping the steel strip above it, until the strip is strongly attracted to some of the teeth. The teeth attracting the strip are those between which lies the shorted coil.

Like most other electrical parts, the field windings may contain shorts or grounds, open circuits or high resistance. To make the tests it is first necessary to disconnect the fields from other conductors and current carrying parts. Disconnecting an outside wire will often isolate one end of the field, and lifting the brushes from the commutator, especially the third brush, will often isolate the inner end of the field circuit. Sometimes removing a field fuse will make the necessary open connection. The test connections for troubles in the field of a third brush generator are shown in Figure 229.

FIELD TROUBLES

Troubles that occur in the fields may take the form of burned out or broken windings or connections, of disconnected terminal fastenings, or of ground connections made with the core or dynamo frame. It should be possible to secure a connection from one end of the field windings through to the other end with the drop-cord circuit tester and the lamp

should light. Failure to secure such a connection indicates a broken or disconnected field circuit. With one of the test wires attached to the metal of the dynamo, the lamp should not light when the other end of the test wire is touched to either end of the field coil while the coil is disconnected from all other circuits and from the brushes and commutator. It should be noted that no circuit test, either to find whether a circuit is complete or grounded, is of any value unless the lines to be tested can be separated from all other connections during the test. Should any outside wiring be left connected, the circuit may be completed through another path than the one being tested and erroneous conclusions will be drawn in many cases.

If the flow of current around the fields should be reversed from its usual direction, the residual magnetism remaining would be of opposite polarity from the normal, and when the dynamo was again used its terminal polarity would be changed. That is, the terminal that was positive would be negative and the terminal that was negative would be positive. Should this condition remain, the dynamo would send its current through the battery in the wrong direction with the result that the battery would suffer an extremely rapid discharge and would soon be damaged permanently.

In order to restore the field magnets to the proper polarity it is necessary that a flow of current be sent through the windings in the proper direction. Should a test at the dynamo show that the current flow remains in the wrong direction, it may be corrected as follows: First make sure that the connections between dynamo and battery are correctly placed. This

means that the positive side of the battery should be connected to the dynamo terminal that should be positive, while the negative side of the battery should be connected to the dynamo terminal that should be negative. With these connections made, with a fully

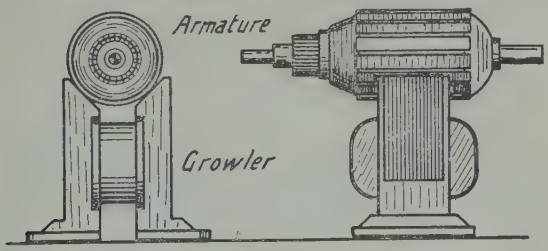


Figure 228.—Short Circuit Armature Test with Growler.

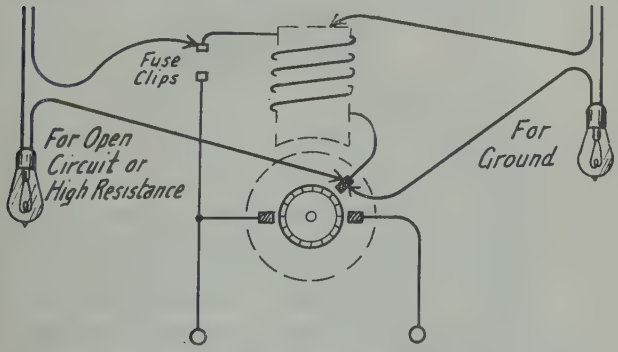


Figure 229.—Field Tests on Third Brush Generator.

charged battery, and with the dynamo idle, the cut-out should be closed several times and allowed to remain closed for two or three seconds each time. Should the cut-out tend to remain closed (if of the electromagnetic type), starting the engine will allow

it to open. The flow of current through the dynamo under these conditions will restore the proper po-

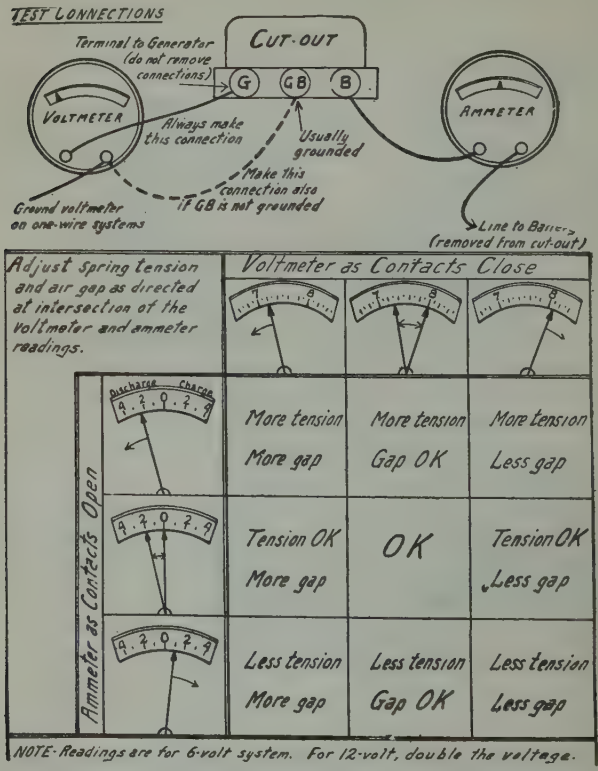


Figure 230.—Voltmeter and Ammeter Readings on Cut-out Test.

larity at its terminals. Many types of dynamos now in use change their polarity to that of the battery the first time that the cut-out closes, and in this case it

would not matter which way the connections were placed as far as the dynamo and battery were concerned.

THE CUT-OUT

Cut-out Care.—Manual or hand-operated cut-outs require the same care and attention as called for by any other type of switch. Electromagnetic cut-outs are of more complicated construction and are subject to a different class of faults.

The contact points of an electromagnetic cut-out should be kept clean and bright and should meet evenly and over their entire surface when the cut-out is closed. Should plain surface contacts be found

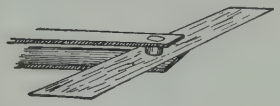


Figure 231.—Cleaning Contacts.

dirty or pitted, they may be cleaned by drawing strips of thin emery cloth between them while holding them lightly together. See Figure 231. This method of using the emery cloth will also restore the surfaces to such a form that they make full contact in case they have become out of line for any reason.

When the engine runs at a charging speed, the cut-out contacts should be closed by the action of the magnet, provided the dynamo is giving the necessary voltage. Failure of the cut-out to close when the dynamo is in good condition will usually be caused by loose or dirty connections of the wires on the cut-out terminals or possibly from a broken or burned out shunt winding in the cut-out magnet. If the

cut-out closes, but does not complete the circuit for charging, the contacts should be examined and the terminal connections of the wires should be made clean and tight.

The contacts of an electromagnetic cut-out should not be pressed together unless one of the wires from either battery or dynamo can be quickly removed. With the contacts together the flow of battery current around the series coil and through the shunt winding may hold them closed with a resulting discharge from the battery. All cut-outs are not subject to this action, those in which the armature never comes very close to the magnet core generally being free from it. Removing the wire that leads to the dynamo or the one that leads to the battery will stop the flow of current and will allow the contacts to open. Starting the engine will stop the flow from the battery and send it in the other direction. When the engine is allowed to stop, the contacts will open.

REGULATING PARTS

It should be noted in connection with the adjustment of regulating devices and the consequent changing of dynamo outputs that this is necessary only under exceptional conditions. The adjustment made by the manufacturers of the car or of the electrical equipment is correct for that car under average conditions, and it should never be altered until the person doing the work is sure of reasons sufficient to warrant the change. It will usually be found that low dynamo outputs are due to lack of proper care in cleaning brushes and commutators, in keeping wire connections clean and tight and in keeping the battery clean and filled with pure water.

It is, however, possible that unusual conditions of service may call for a change in dynamo output. For instance, a car that is driven mostly at night with the lamps lighted may require that the dynamo have a greater output than for one that is driven under usual conditions. The addition of electrical accessories sufficient to make a load on the system greater than it was designed to handle is not a good reason for increasing dynamo output, and doing so under these conditions will usually result in permanent damage to the electrical equipment.

As a general rule the dynamo output should be greater in winter than in summer because of the lower efficiency of the battery and the greater use of the lamps and starter at this time. During a long tour it may be advisable to lower the charge rate or to stop the charge altogether, by short circuiting the dynamo terminals, by opening a touring switch, if one is provided, or by removing a field fuse.

Any form of magnetically controlled field resistance operating on the vibrating principle requires that the regulator contacts and terminal connections be given the same care as outlined for the electromagnetic cut-out. The contacts, when dirty, may be dressed by using very fine emery cloth drawn between them, and in this connection it should be noted that improper wiring of the controller may result in sending the charging current through the regulator contacts, which will result in rapid pitting and burning of the surfaces.

The reversed series field winding is not subject to any troubles that are peculiar to its regulating functions provided it has been properly designed and installed when the dynamo was built. This field

winding is, however, subject to the same troubles that may be encountered with any shunt or series field and methods of locating such troubles have already been given.

Adjustment or repair of the thermostat should rarely be attempted, it being more satisfactory to install a new unit in case of trouble. If the screw by which the field line is attached should be turned, no weight or downward pressure should be put on the screwdriver because the thermostat frame may be bent. The contact points should never be forced apart as the blade might be sprung and the action rendered incorrect. Should the resistance coil be broken or burned out the dynamo will generate while cold and as long as the points remain in contact, but as soon as heat develops the points will separate and prevent any flow of field current or any output from the dynamo until it cools sufficiently for the points to again close. Such a condition as that just described will cause severe burning of the contacts and they may possibly weld together. Should the contacts remain closed the dynamo will give its high output continuously and may thereby cause damage to the battery and the dynamo itself. A burned out resistance indicates trouble such as a loose connection, a corroded battery terminal or an open circuit in the charging lines.

The third-brush system adds nothing to the dynamo for regulating purposes except the extra regulating brush. These brushes require the same careful fitting that would be called for with any other current-carrying brushes and the field winding itself does not differ in any important particular from other shunt windings and may therefore be handled in the same way.

Third Brush Adjustment.—The shunt field is connected between the third brush and one of the main brushes and the voltage acting on the field depends on the distance of the third brush from the main brush attached to the other end of the field. Moving the third brush farther away from the main brush of opposite polarity will decrease the dynamo output, while moving the third brush toward that main brush will in-

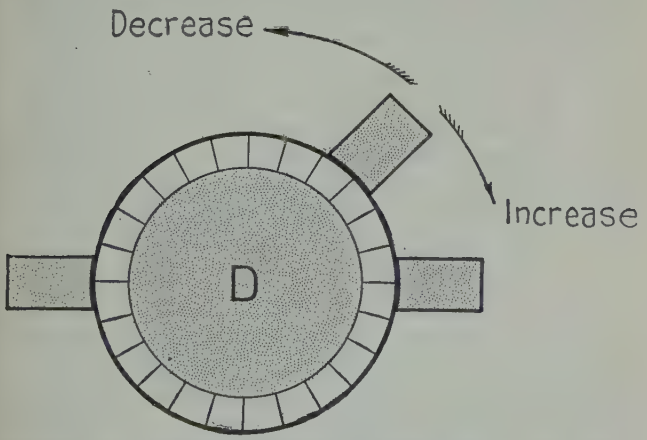


Figure 232.—Changing Dynamo Output by Moving Third Brush.

crease the output. This is shown in Figure 232. Easily operated adjustments may be built into the dynamo or it may be necessary to move the brush holder on its fastenings in order to change this position. Before a third brush is moved, the brush end and commutator should be cleaned and after the adjustment is completed they should be cleaned and fitted. The battery should be well charged before making this adjustment.

STARTER TROUBLES

The starting motor is subject to the same electrical troubles as the generator in its armature, commutator, brushes, and field windings. The starting switch may have the same troubles as any other switch; dirty, loose, bent or broken contacts, etc. It is especially necessary that all terminal connections be kept perfectly tight and clean because of the large amperage to be handled.

With the Bendix type of screw pinion shift the screw threads should be kept clean and dry, not oiled under any circumstances. If the pinion sticks and will not mesh with the flywheel gear, it may be loosened by tapping with a hammer. If it sticks in mesh, it may be released by putting the transmission in high gear and, with the clutch engaged, rocking the car back and forth. If this fails, the flywheel may be pried around by catching a bar between the gear teeth. A twisted or broken spring indicates a kick back of the engine while starting or improper assembly of the drive parts. Attempting to use the starting motor with a broken spring will chip or break the flywheel teeth.

Starter drives having sliding gear shifts should be kept clean and sliding surfaces should be lubricated with heavy oil or by means of grease placed in the cups. This lubrication should be cared for at least every week if trouble is to be avoided. It may be found that drive shafts have become bent through binding or improper use of the starting pedal, and in some cases it will be found that gear shifting and switch return springs are not heavy enough for the work to be done, especially on new cars before the parts have been fully worked in. Overrunning clutches

should be lubricated with vaseline or rather thin grease of good quality and the starting pedal should never be held in the starting position long enough to cause the clutch to be run at high speed. This will surely result in burning the grease and the final result will be a badly damaged or ruined clutch.

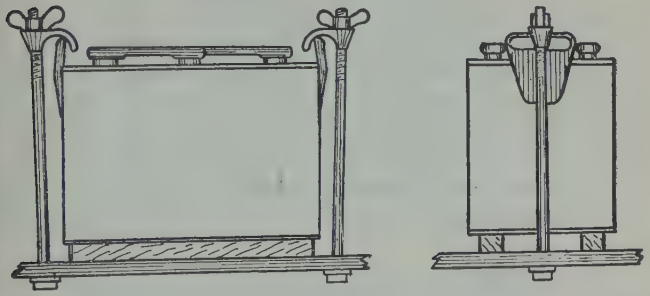


Figure 233.—Correct Fastening for Battery.

BATTERY CARE

It is very essential that the storage battery have certain attention at regular intervals. The most important item in the care of a battery is that of adding pure water to each cell at least once each week during warm weather and at least every second week in cold weather while the car is in use. The water is added through the holes left with the vent plugs removed and may be easily handled by using the hydrometer syringe. A sufficient quantity of water should be placed in each cell to bring the surface of the liquid from one-quarter to one-half inch above the tops of the plates, this point being indicated in most cases by a rim that can easily be seen at the bottom of the hole with the plug removed.

The water used for this purpose must be distilled or else perfectly clean rain water. Tap water or water that has been kept in metal containers must never be used. Some city waters may be used, but it will always be necessary to make an analysis before their safety can be determined. Except when some of the electrolyte has been spilled from one of the cells, nothing but pure water should ever be added. In no case should undiluted sulphuric acid be used. If it is known that a part of the electrolyte has been lost through other means than by evaporation and the slight spray from gassing, the level may be brought up in the low cell by testing the gravity in the adjoining cells and then making enough electrolyte of this gravity to bring the level in the low cell to the required point.

Electrolyte is made by slowly pouring chemically pure sulphuric acid into distilled water until a mixture of the desired gravity is reached. Two and one-half parts of water to one of acid will make a mixture of about 1.300 specific gravity. Lower gravity is secured by adding more water. The mixture must be allowed to cool before it is added to the cell. If the water is poured into the acid, a violent action and throwing of liquid will take place.

The specific gravity of each cell of the battery should be taken at regular intervals, and if the whole battery is getting lower the fault should be looked for without delay. If one cell becomes lower, but the others remain normal, trouble in that cell is indicated. Care should be used when testing not to spill electrolyte on top of the battery, as it will cause corrosion at the terminals and partial short-circuiting of the cells. If it is found that one cell always takes more

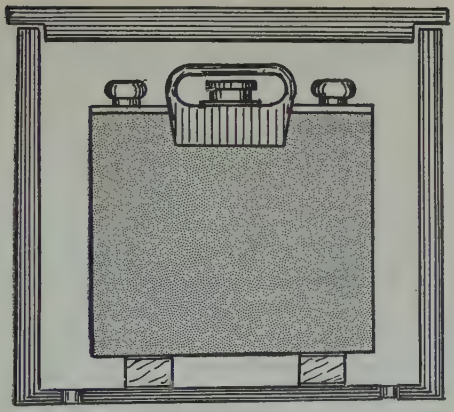


Figure 234.—Air Space Around Battery in Box.

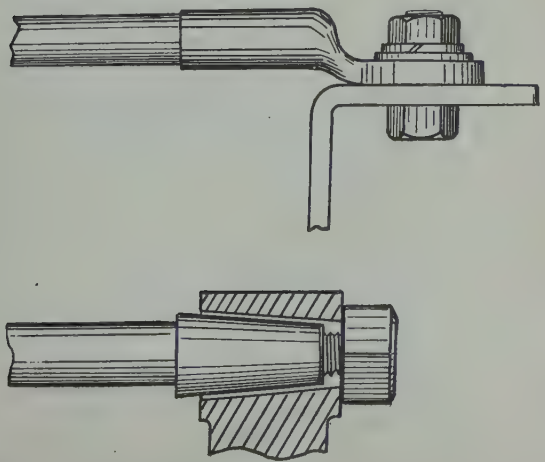


Figure 235.—Ground Connection at Top, Battery Taper Terminal at Bottom.

water than others, it is probable that the jar for that cell has become broken. The level of the liquid in the cells should not be above a point one-quarter to half an inch above the tops of the plates, because during charge the gassing that occurs will cause the electrolyte to overflow and cause damage outside of the cells.

At the time of testing or adding water to the battery, the terminals should be carefully examined for looseness or breakage, either at the connecting bars between the cells or at screwed or tapered connectors. No copper wires should ever be attached at the lead battery posts, as they will soon be eaten away by the action of the acid. Should the connections be found covered with corrosion or verdigris, they should be washed with ammonia water, and in any case should be covered with a coat of vaseline to prevent such action by the acid.

The battery must be firmly secured in its box so that movement from the motion of the car is impossible. Wood cleats should be placed under the battery and fastened into the bottom of the box. The space all around the battery and on top should be free and open for the circulation of air. The best method of holding the battery is by using hooked bolts that catch on the battery handles and screw down tight. If the battery case is wet or if the inside of the battery box is wet, the moisture should be wiped away with a cloth slightly wet with ammonia water.

It is, of course, essential that the electrical conditions of charge and discharge be correct for the battery. These points are taken up in other parts of this book, but it should be noted that the dynamo should give such an output at fifteen miles an hour

car speed that the battery is not being discharged with all lamps turned on. It should also be remembered that the demands on the system and on the battery are much greater in winter than in summer. The efficiency of the battery is much lower when cold than when warm, and the dynamo does not give an output as great as would be required for the extra lamp load imposed by the greater number of dark hours, and also by starting a cold engine under winter conditions. Therefore, the battery should have the very best of care during cold weather. Lamps should be used as economically as possible, and, if convenient, lower candlepower bulbs should be substituted in the lamps. The engine should be started by hand for the first time on cold mornings, and at all times the carburetor and ignition should be in such adjustment and condition that but a very few seconds' cranking with the motor will suffice to start the engine. Care of this kind will do more than anything else to insure satisfactory operation of the whole electrical system, because nothing else can do its work unless the battery is in good order and properly charged.

REVIEW OF CHAPTER VIII

UPKEEP, CARE AND REPAIR

With an **open circuit** the current path is not complete from one side of the source back to the other side. **High resistance** at any point in a circuit produces effects somewhat similar to open circuits.

With a **short circuit** current from the positive of the source returns to the negative without having passed through the conductors and units which it should operate. A **ground** is a short circuit in which the current returns through the metal or ground of the car.

Open circuits or high resistances are located by bridging around the suspected parts with a voltmeter, the meter showing high voltage when the trouble is bridged. With a lamp circuit tester, these troubles are located by failure of the lamp to light.

Shorts and grounds are located with a voltmeter by placing the meter in series with the circuit, then opening successive points while working away from the battery. A drop in voltage indicates that the fault is located between the point then opened and the last one opened. These troubles are located with a lamp circuit tester by the lamp's lighting when the shorted or grounded conductors are being touched.

With two live conductors immersed in water containing salt or acid, the **negative conductor** will give off more bubbles than the positive.

Lamps should be focused to give a clear and well defined beam of light, and the supports then moved to direct the light to the proper point on the road.

Failure of lamps to light or dim light may be due to: Looseness of the lamp case, the reflector, or wires in the lamp. Bulb burned out, of wrong base type, or of too high voltage. Socket plungers or springs not making contact. Wires shorted or grounded. Wires disconnected or loose. Switch contacts bent or worn to prevent contact, or wrong connections at switch. Loose switch parts will also cause trouble. Fuses burned out or loose in clips. Circuit breaker open.

Brushes may have the following troubles—Not properly fitted, burned off, or worn out. Binding or loose in holders, insufficient pressure.

Commutator troubles include—Rough, pitted, or worn in grooves. High mica. Loose bars or high bars.

Armature troubles include—Grounds, short circuits, open circuits, and high resistance.

Field troubles include—Open circuits, high resistance, shorts and grounds, reversed connections. Burned out field fuse. Demagnetized.

Trouble in third brush systems may be due to any of the brush or commutator troubles.

Vibrating regulators for constant amperage or constant voltage may have dirty or pitted contacts, wrong connections at their terminals, wires loose, or dirty contacts. The fine wire winding may be burned out.

If the **resistance of a thermostat** system burns out, there will be no charge after the generator gets hot.

The **electromagnetic cut-out** may have the following troubles—Loose or dirty terminal connections. Dirty or pitted contacts, sticking contacts or arm. Broken or loose spring. Wrong connections at terminals. Improper adjustment of spring tension or armature gap. Burned out fine wire winding.

CHAPTER IX

MAKES AND TYPES OF EQUIPMENT

In the following pages are given brief descriptions of the chief characteristics of the generally used makes and types of electric starting and lighting equipment. Detailed descriptions of the construction and operating principles have been given in the preceding portions of this book and in case such information is desired on any particular system, it may be found by reference through the index.

It will be found that the double voltage systems, in which a higher voltage is used for starting than for charging, are no longer in evidence and that almost all of the equipments operate at six volts nominal pressure. Almost all equipments are of the single-wire, ground-return type. The dynamo, the starting motor and the ignition are generally separate units, although a considerable number mount the ignition breaker and distributor, and even the coil, on the dynamo. The majority are now using the third brush system of current regulation.

About one-half of the batteries are either between ninety and one hundred ampere-hour capacity or between one hundred and ten and one hundred and twenty ampere-hour capacity at six volts; these two popular sizes being represented in practically equal numbers. The remainder of the field is divided between various other capacities.

ALLIS-CHALMERS

This is a motor-generator system with a vibrating type of constant current regulator allowing a maximum of 10 to 12 amperes at 6 volts. As shown in Figure 236, the machine is a four-pole, four-brush

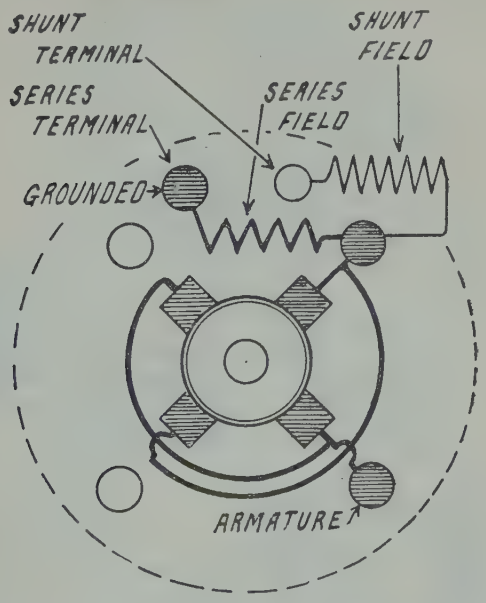


Figure 236.—Allis-Chalmers Motor-Generator.

unit with shunt and series windings. The combined regulator and cut-out unit is mounted on the dash with the switches for lighting and ignition. The starting switch has an auxiliary contact which opens the generator circuit while the starting contacts are closed.

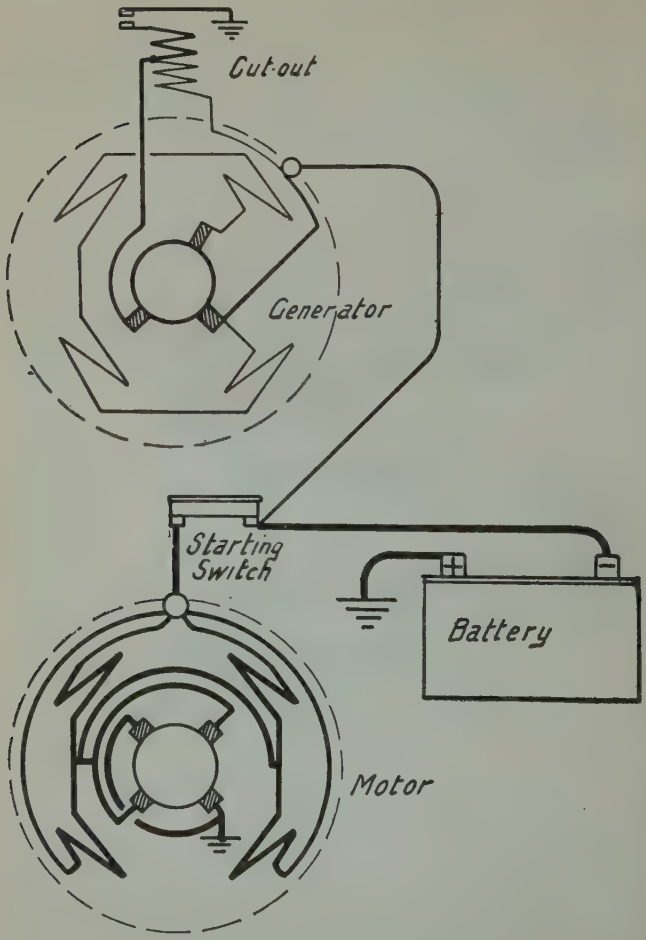


Figure 237.—Atwater Kent System.

ATWATER KENT

The generator and motor are shown in Figure 237. The generator is a four-pole shunt wound type with third brush regulation allowing a maximum output of 12 to 15 amperes at 6 volts. The electromagnetic

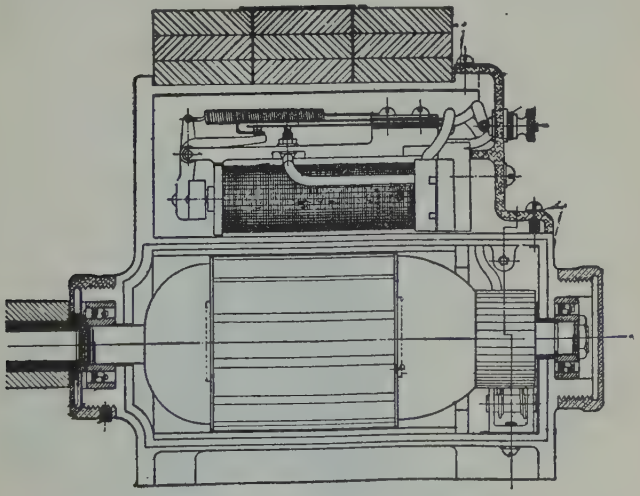


Figure 238.—Auto-Lite Permanent Magnet Generator.

cut-out is carried on the generator. The starting motor has all four of the series field coils connected to the terminal on one side and to two brushes on the other side. The other two brushes are grounded.

AUTO-LITE

The first Auto-Lite systems used a permanent magnet generator with an electromagnetic cut-out under the arch of the magnets as shown in Figure

238. The generator drive is through a slipping clutch governor which, with the permanent magnet field, gives constant voltage above 1800 R. P. M. with a maximum output of 13 amperes.

The next equipment included a generator with a U-shaped field magnet carrying a shunt and a reversed series field winding together on the top of the magnet as shown in Figure 239. The maximum out-

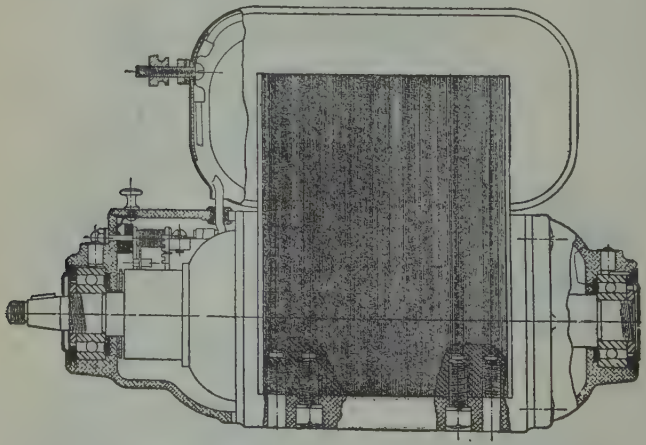


Figure 239.—Auto-Lite Single Coil Reversed Series Generator.

put of this machine is about 16 amperes. A separately mounted electromagnetic cut-out is used. The cut-out has both copper and carbon contacts.

Square frame Auto-Lite generators are of two types; one a reversed series machine as shown in Figures 70 and 240, the other a third-brush machine as shown in Figure 241. The reversed series machines of types "GB" and "GC" have a maximum output

of 14 to 15 amperes, and of types "GD" and "GG" a maximum of about 12 amperes. The third-brush machines, type "GH," have a maximum output of 16 amperes. Electromagnetic cut-outs shown in Figure 112 are used with both kinds of generators,

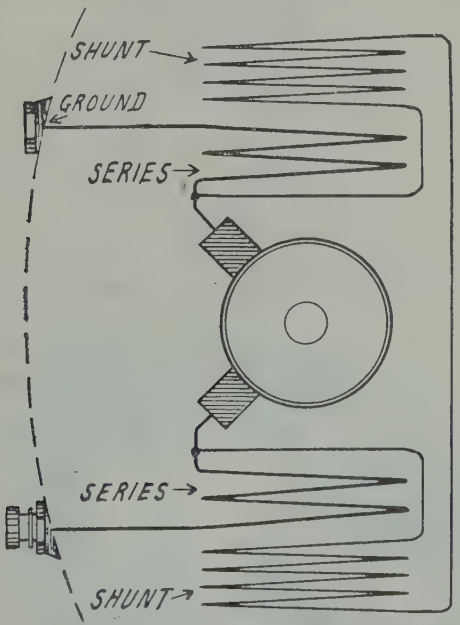


Figure 240.—Auto-Lite Square Frame Reversed Series Generator.

being mounted on the generator or as a separate unit.

Later types of Auto-Lite generators are of the third-brush contruction with round frames as shown in Figures 242 and 243. The maximum charge rate is around 16 to 17 amperes. Separate electro-

magnetic cut-outs are used. The connections of Auto-Lite two-wire and single-wire starting motors are shown in Figure 244. Auto-Lite cut-outs are shown in Figure 120.

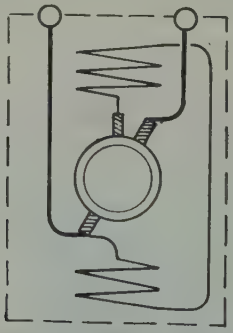


Figure 241.—Auto-Lite Square Frame Third Brush Generator.

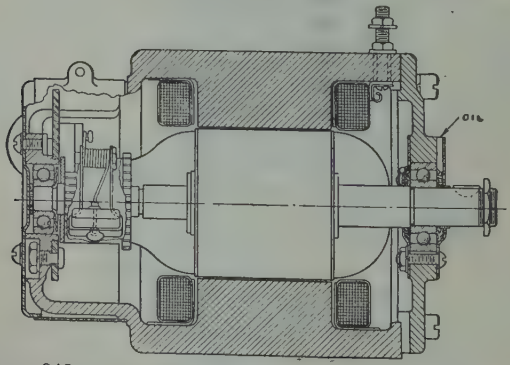


Figure 242.—Auto-Lite Round Third Brush Generator.

BIJUR

Many Bijur systems of the constant voltage type are in use. The four-pole, shunt wound generator is shown in Figure 245. There are three sockets into

which fit three pins of the combined regulator and cut-out shown in Figure 93. This regulator is contained in a box that fits on top of the generator. The

Figure 243.—Auto-Lite Third Brush Generator Circuits.

regulator is adjusted to give between 7¾ and 8 volts with a fully charged battery, which will give a maximum charge rate of 5 to 10 amperes, depending on

Figure 244.—Auto-Lite Starting Motors.

the condition of battery charge. The wires to the battery connect to a socket plug on the regulator, and about every 500 miles the position of this plug should

be reversed to reverse the current through the regulator and protect the contact points from pitting. A constant voltage generator with an internal regulator is shown in Figure 94.

The first generally used third-brush Bijur genera-

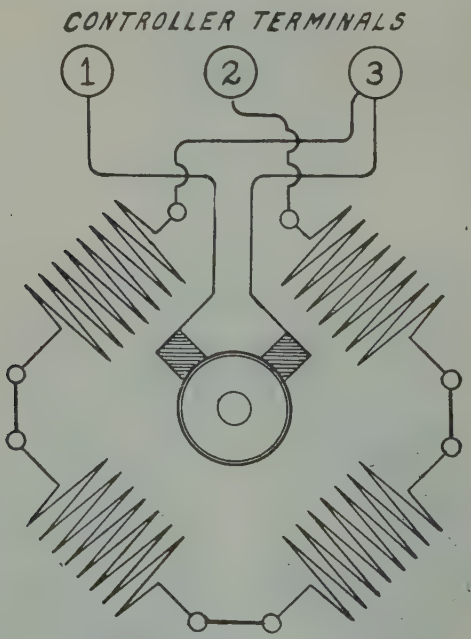


Figure 245.—Bijur Generator for Constant Voltage Control.

tors have their cut-out inside the generator. There are two types, one with two terminals as shown in Figure 246 and the other with one terminal as in Figure 247. Both types use a 10-ampere field fuse. The maximum charge rate for either machine is

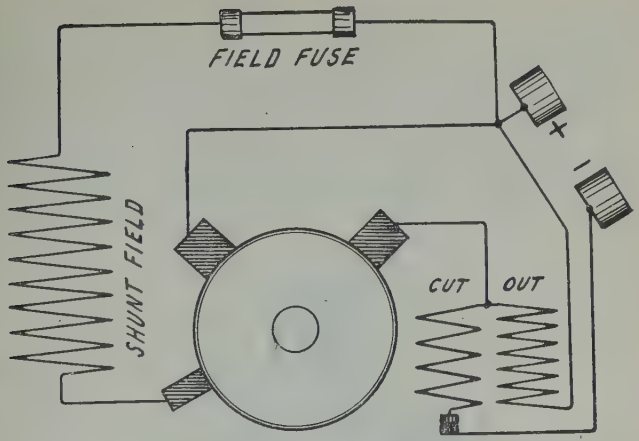


Figure 246.—Bijur Two Terminal Third Brush Generator.

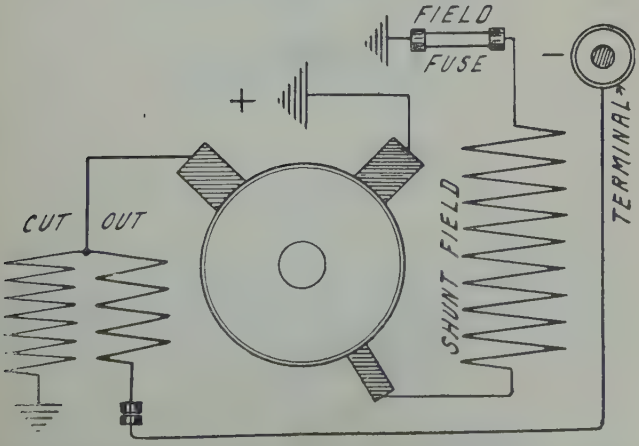


Figure 247.—Bijur Single Terminal Third Brush Generator.

14 to 16 amperes. Bijur cut-outs are shown in Figure 121.

Later Bijur generators are of the third-brush type with a round frame and with the cut-out mounted on top of the generator as shown in Figure 248. These machines also have the 10-ampere field fuse. The maximum charge rate is between 12 and 15 amperes.

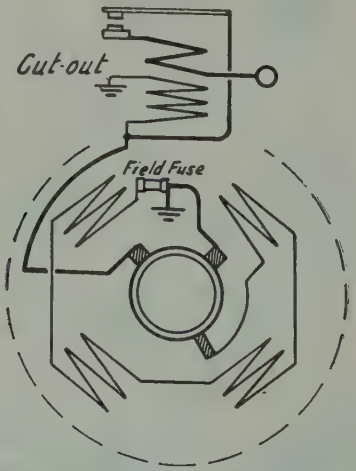


Figure 248.—Bijur Third Brush Generator, Cut-out on Top.

There was one Bijur third-brush motor-generator shown in Figure 249. This machine has four field coils, each one having both shunt and series field windings. It is of the 12-volt type with a maximum charge rate of 7 to 9 amperes.

BOSCH

The Bosch constant voltage system is shown in Figure 250. This is a 12-volt equipment with an

electromagnetic cut-out and a voltage regulator carried in a dash unit with the lighting switch and volt-ammeter. The regulator consists of an electromagnet with a plunger pressing down into a cup containing a mixture of carbon and mica through which the field current flows to ground. A decrease of pressure caused by the generator's voltage increasing through the electromagnet, tends to lift the plunger, lessen

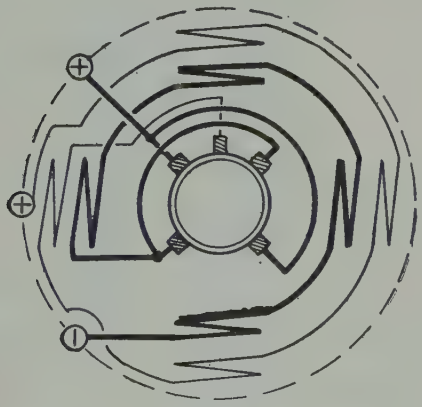


Figure 249.—Bijur Motor-Generator.

the pressure on the carbon-mica mass, and allow an increase of resistance in this mixture so that the field current is reduced to lower the generator voltage. Adjustment of the regulator screw is made to maintain 14 to 15 volts, which will allow a charge rate of 8 to 10 amperes with a charged battery.

The Bosch "Standard" lighting and starting system is of either 6- or 12-volt type. The Types DSG 105 and 106 are compound wound with the

lamp current taken through the series winding to increase the output with lamps on. The other types have reversed series control. The circuit connections for the compound wound generators are shown in

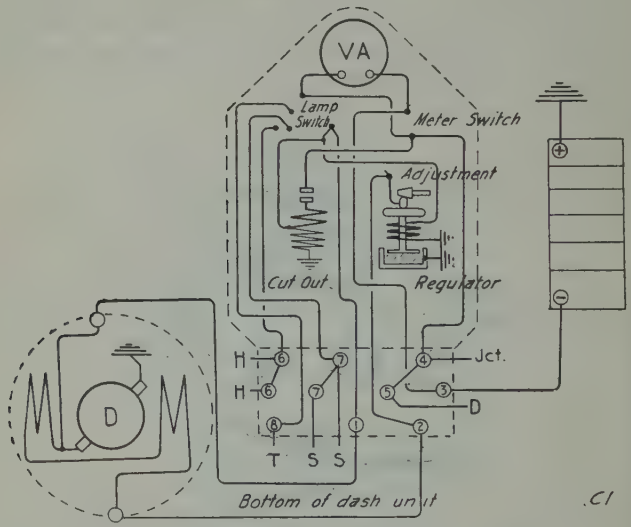


Figure 250.—Bosch Constant Voltage System.

Figure 251, and for the reversed series machines in Figure 252. The maximum output varies with the type number of the generator. For the 6-volt machines, number 106 gives 10 amperes, number 108 gives 12 amperes, number 6 gives 14 amperes, and number 8 gives 17 amperes. For the 12-volt machines, number 105 gives 5 amperes, number 107 gives 6 amperes, number 5 gives 7 amperes, and number 7 gives 8 to 9 amperes maximum. The cut-out is

carried in a control box together with the switches, a 30-ampere main fuse, and a 3-ampere field fuse.

The later Bosch equipment includes a third-brush, four-pole, shunt wound generator. These machines

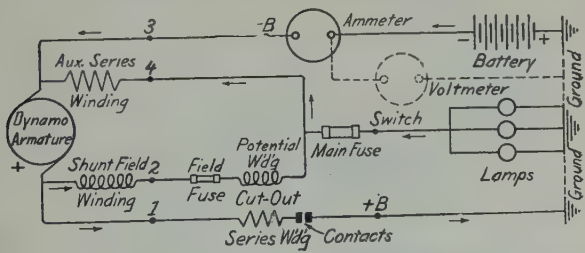


Figure 251.—Bosch Standard System, Compound Generator.

have a round field frame, the 4-inch size giving a maximum output of 10 to 12 amperes, and the 5-inch size giving 14 to 16 amperes. The electromagnetic cut-out shown in Figure 122 is on top of the genera-

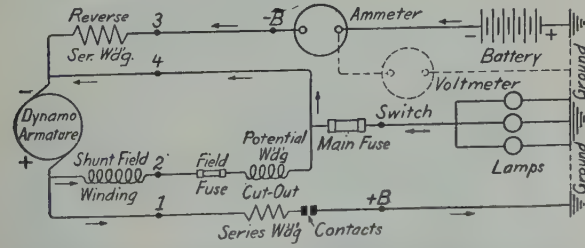


Figure 252.—Bosch Standard System, Reversed Series.

tor. The 6-volt generator and starting motor are shown in Figure 253. A 5-ampere field fuse is mounted on the generator.

The Bosch-Rushmore equipment used a generator with iron wire control as shown in Figures 106 and

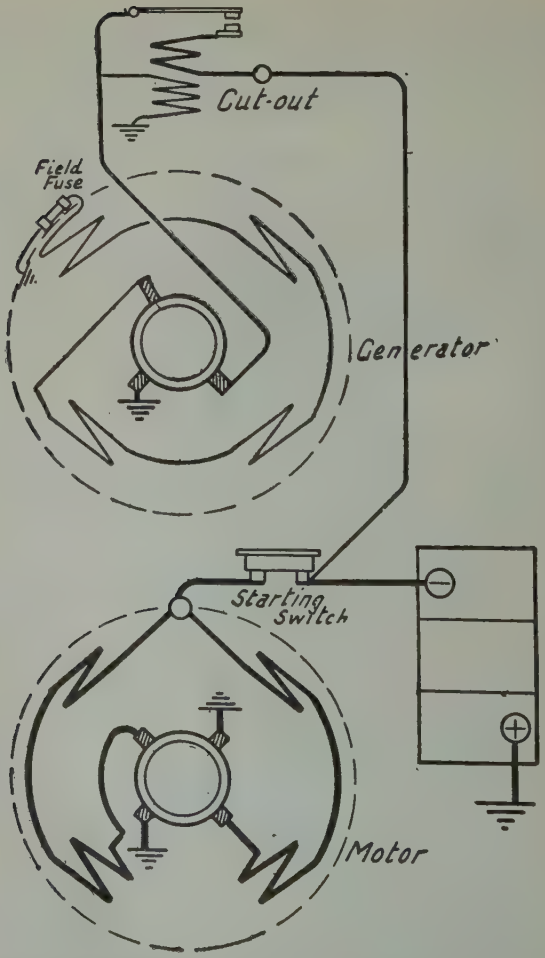


Figure 253.—Bosch Third Brush Generator with Motor.

254 and a starter motor with the magnetic pinion shift shown in Figures 197 and 198.

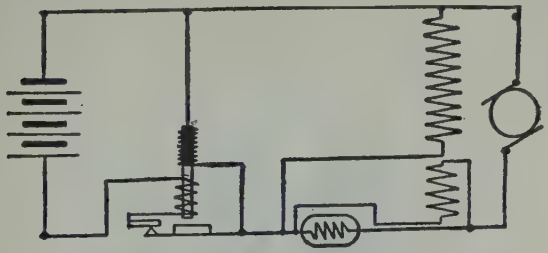


Figure 254.—Rushmore Iron Wire Generator Control.

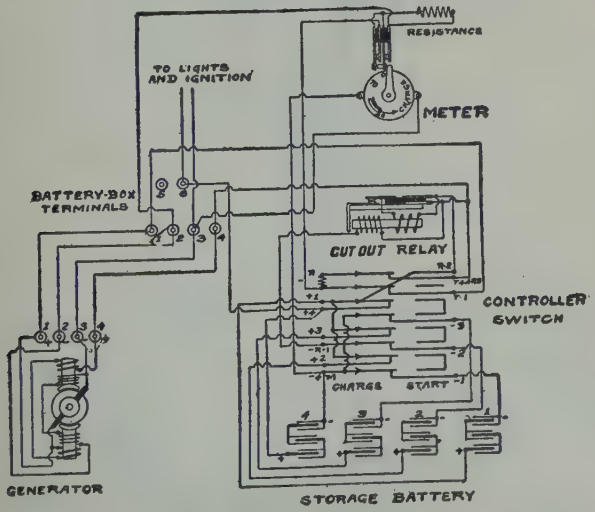


Figure 255.—Delco 6-24 Volt Motor-Generator System.

DELCO

The first Delco systems used 6-volt charging and lighting with 24-volt starting, the connections and

operation being shown in Figures 104 and 255. The maximum output of this system is around 18 to 22 amperes.

Many Delco motor-generators used the mercury well constant voltage control shown in Figure 256.

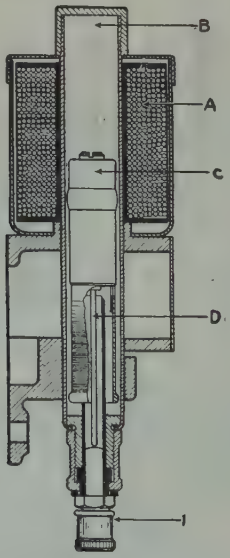


Figure 256.—Delco Mercury Voltage Regulator. A—Winding. B—Cylinder. C—Plunger. D—Mercury Well. I—Field Terminal.

The internal connections of one of these machines are shown in Figure 257. This machine, together with many of those shown in the following diagrams, uses the motor brush type of starting switch as shown in Figure 184. The output of the mercury well machines depends on the condition of the battery

charge, generally running about 10 amperes. Most of these motor-generators have been rebuilt into a reversed series type having a maximum output of about 20 amperes at 6 volts.

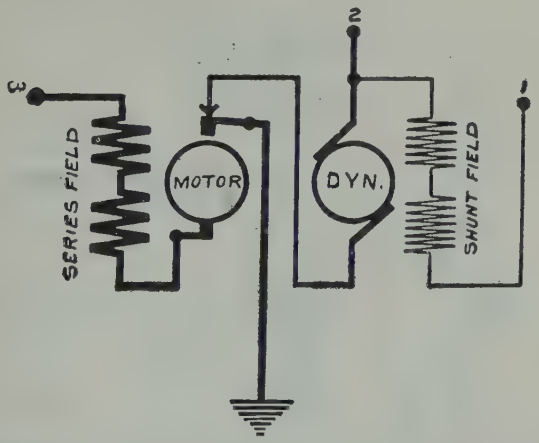


Figure 257.—Delco Motor-Generator for Mercury Regulator.

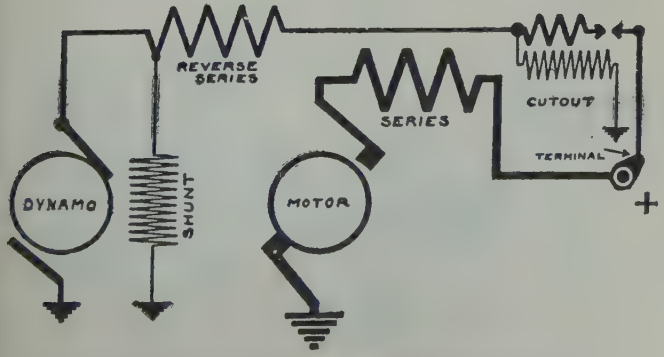


Figure 258.—Delco "Junior" Motor-Generator.

Delco motor-generators of the "Junior" types are shown in Figures 258 and 259. The first of these machines had an electromagnetic cut-out in the upper part of the motor-generator housing, while the later

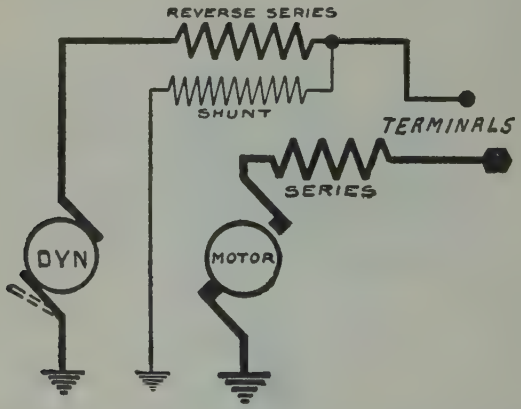


Figure 259.—Delco Reversed Series Motor-Generator.

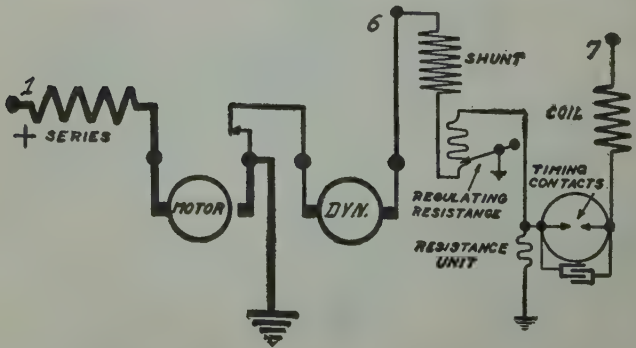


Figure 260.—Delco Centrifugal Governor Motor-Generator.

ones had a manual cut-out combined with the ignition switch. The maximum output at ordinary car speeds for either type is about 15 to 16 amperes. These machines use one armature with two commutators.

During 1915 and 1916 a large number of Delco motor-generators were made with the centrifugal

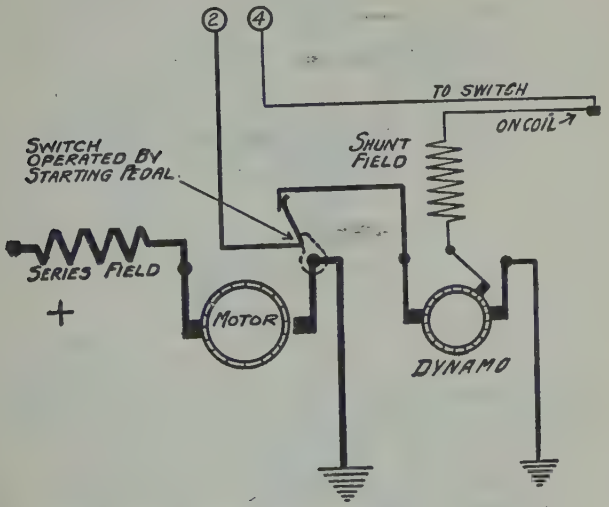


Figure 261.—Delco Third Brush Motor-Generator.

regulator shown and described in Figures 102 and 103. The circuit connections are shown in Figure 260.

With these machines the output drops off with the highest speeds. The maximum rate depends on the type of machine and the regulator spool installed, but runs between 18 and 22 amperes for all. The cut-out is of the manual type, combined with the ignition switch.

A few motor-generators were built with reversed series field windings and also a constant current regulator as shown in Figure 78. The usual setting allowed a maximum output of 16 amperes.

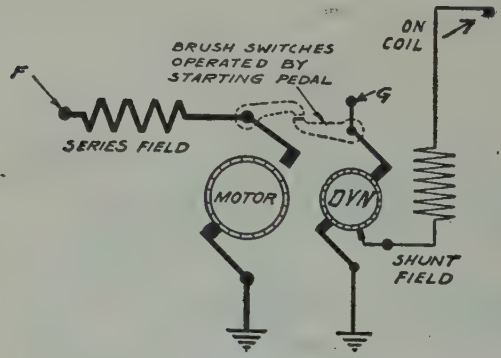


Figure 262.—Delco Third Brush Motor-Generator (Buick).

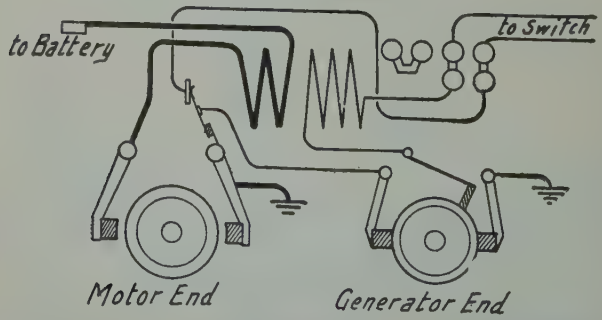


Figure 263.—Delco Third Brush Motor-Generator (Cadillac).

The construction of a typical third-brush Delco motor-generator is shown in Figure 68, and the cir-

cuit connections for this machine are shown in Figure 261. A machine of the type used on Buick cars is shown in Figure 262. Depending on the set-

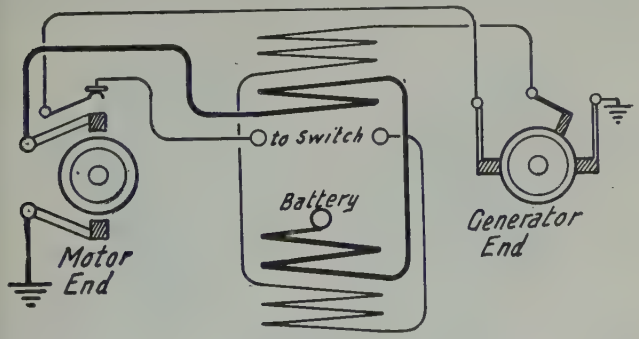


Figure 264.—Delco Third Brush Motor-Generator (Hudson).

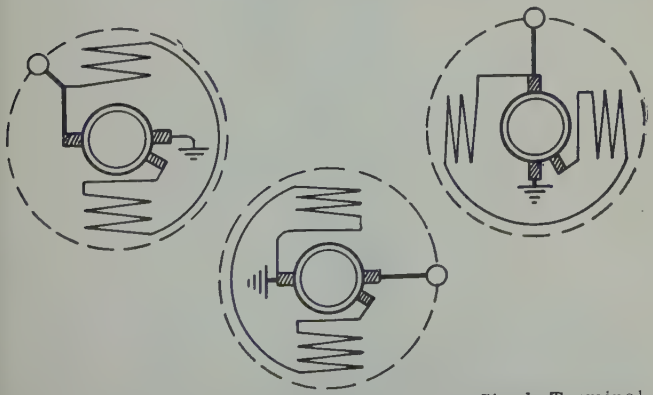


Figure 265.—Delco Third Brush Generators, Single Terminal.

ting of the third brush, the maximum output of these third-brush machines runs from 12 to 20 amperes. A Cadillac motor-generator of this third-brush type

is shown in Figure 263 and a Hudson unit in Figure 264.

Among the earliest separate generators of Delco make was the single field coil third-brush machine

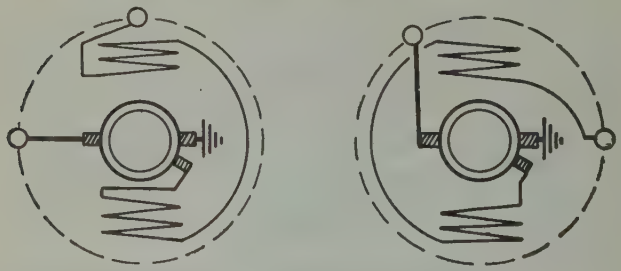


Figure 266.—Delco Third Brush Generators, Two Terminals.

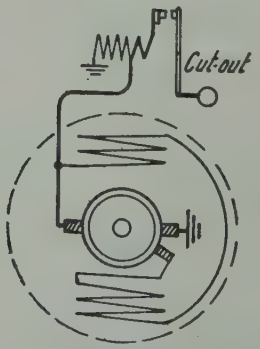


Figure 267.—Delco Third Brush Generator with Cut-out.

shown in Figure 66, with which the maximum output runs from 16 to 20 amperes.

Delco separate generators of both two-pole and four-pole types with third-brush regulation are built in many different styles. Machines having a single outside terminal, no cut-out, and two field coils are

shown in Figure 265. Those with two outside terminals, no cut-out, and two field coils are shown in Figure 266. Figure 267 shows the machine having

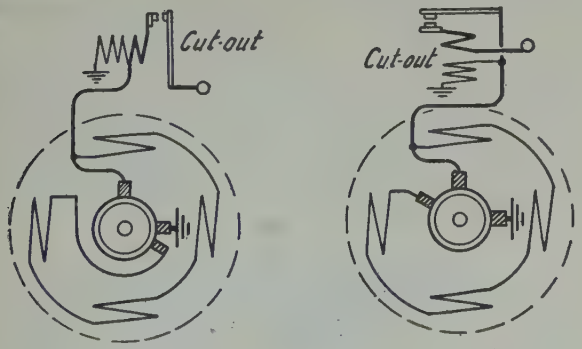


Figure 268.—Delco Third Brush, Four Coil, Generator.

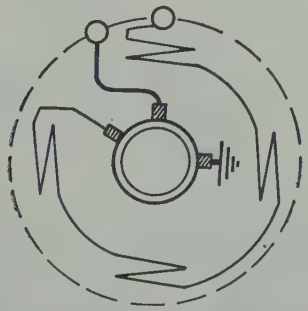


Figure 269.—Delco Third Brush Generator for Voltage Control.

two field coils and an electromagnetic cut-out, while Figure 268 shows the four field coil type with a cut-out. The cut-outs are shown in Figures 114 and 115. Depending on the setting of the third brush, the

output of all of these generators will be between 14 and 18 amperes maximum.

In Figure 269 is shown the third-brush generator that also uses the combined cut-out and voltage regulator of Figure 95. This voltage regulator does not act until the battery reaches full charge; up to that time the output being controlled by the third brush. Adjustment of the voltage regulator is made only with the battery fully charged. On the 6-volt generators the regulator is set for 7¾ volts and on the 12-volt outfits for 15 volts.

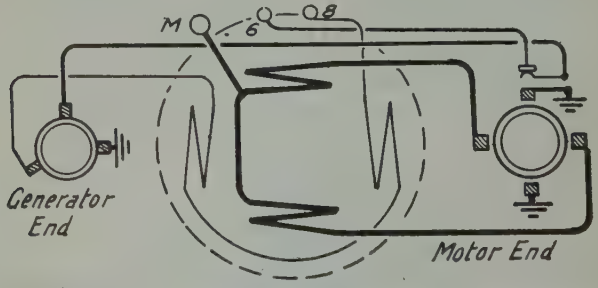


Figure 270.—Delco Round Motor-Generator, Positive Ground.

The round frame Delco motor-generators are shown in Figures 270 to 273. These machines have a starting commutator at one end and a generator commutator at the other end of the armature. Generator shunt fields are on two poles and starter series fields on the other two poles. Some of these machines have a thermostat on the third-brush arm. When the heat of the generator causes the thermostat contacts to open, the field current has to flow through the resistance and the generator output is reduced to about half of normal. The normal maximum rate with the

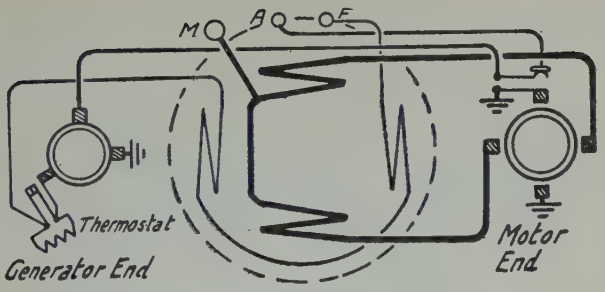


Figure 271.—Delco Round Motor-Generator, Negative Ground.

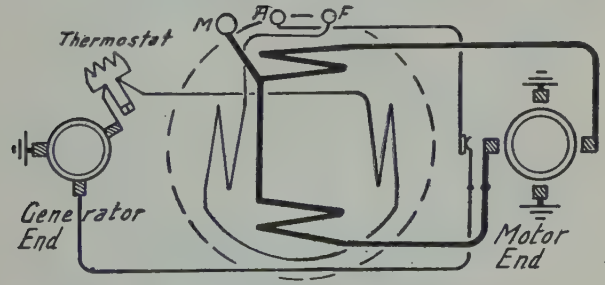


Figure 272.—Delco Round Motor-Generator with Thermostat.

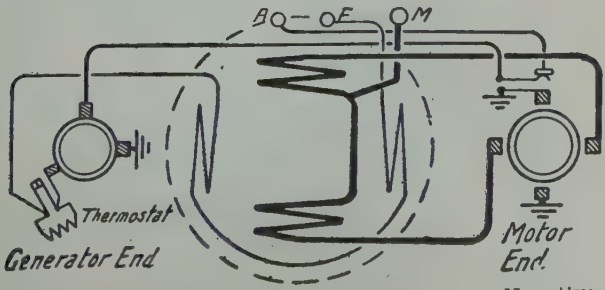


Figure 273.—Delco Round Motor-Generator, Negative Ground, with Thermostat.

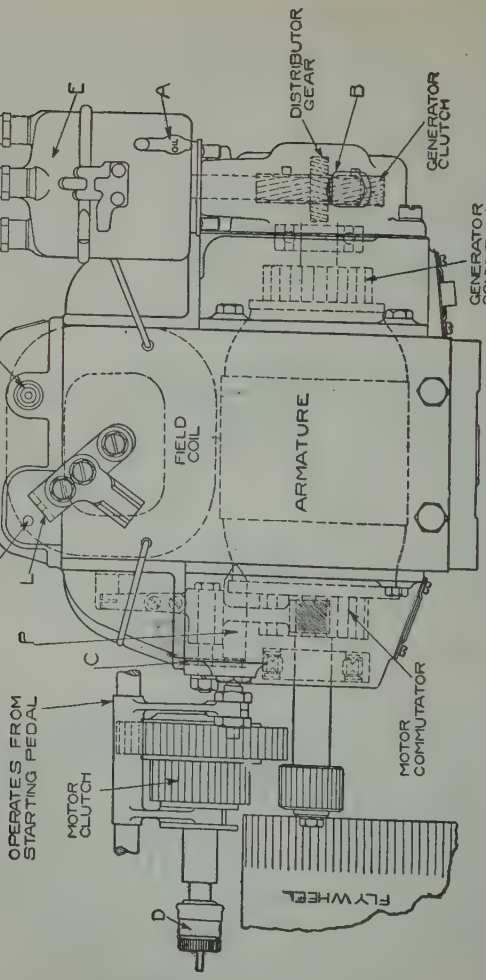


Figure 274.—Delco Starter Drive with Two Ratios.

thermostat closed is 15 to 16 amperes. Starting switch action is secured by lifting and dropping the motor brushes. There is a charging contact on the motor brush arm that opens the generator circuit while cranking.

Several types of Delco starting motors with their field connections are shown in Figure 173. The gearing by which the motor-generator armatures are

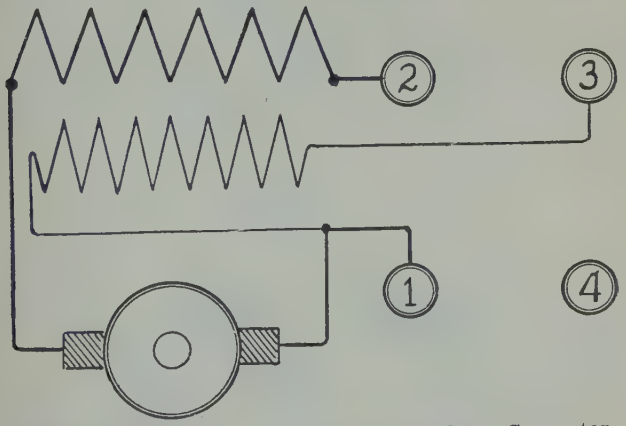


Figure 275.—Dyneto Reversed Series Motor-Generator.

allowed to run faster when generating than when starting is shown in Figures 193 and 274.

DYNETO

Dyneto six-pole motor-generators with a hexagonal frame are of both the reversed series type as shown in Figure 275 and of the third-brush type as in Figure 276. All of these machines operate at 12 volts. The maximum output of the reversed series machine is

10 amperes. The third-brush machine with three shunt coils has an output of 10 amperes, while the machine with six shunt coils gives as high as 15 amperes. No cut-out is used, the battery connections being made when the starting switch is closed.

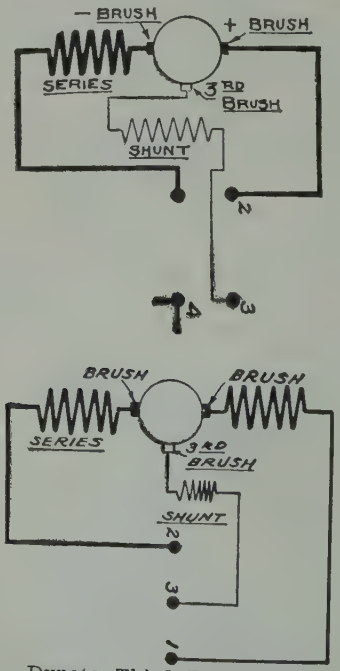


Figure 276.—Dyneto Third Brush Motor-Generators.

The later motor-generators are of the four-pole type with a round frame, having the connections shown in Figure 277. These machines also have no cut-out, the charging connection being made through

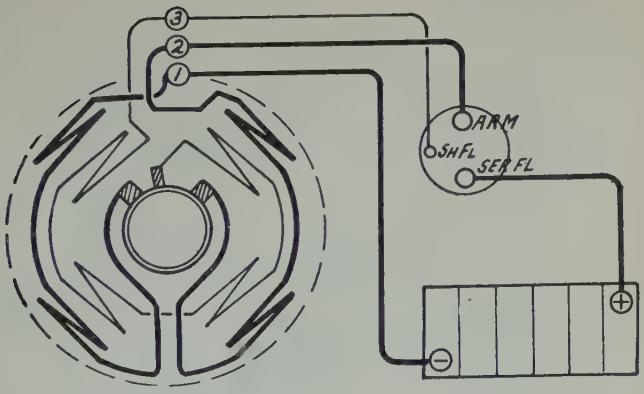


Figure 277.—Dyneto Round Four-Pole Motor-Generator.

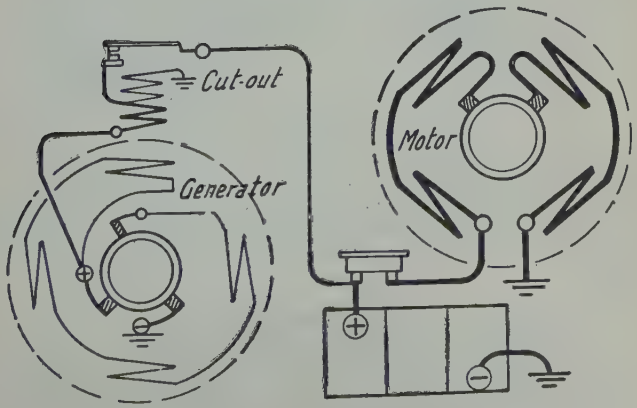


Figure 278.—Dyneto Third Brush Generator System.

the starting switch. The maximum output is 12 amperes at 12 volts.

Separate generators of Dyneto make are of the four-pole shunt wound type with third-brush regulation. The maximum output is between 12 and 14 amperes at 6 volts. An electro-magnetic cut-out is carried on the generator or mounted separately. The

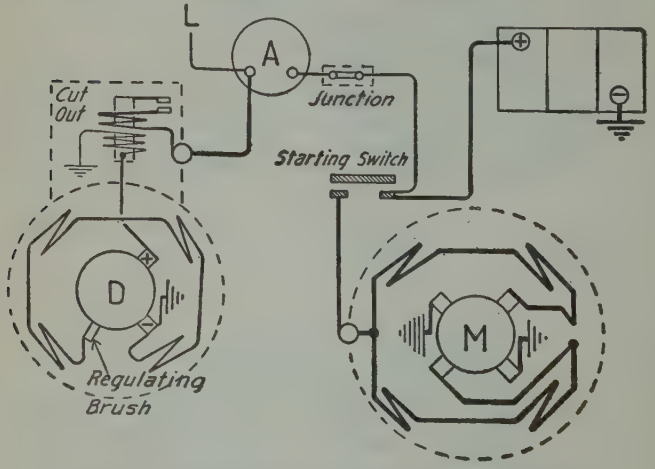


Figure 279.—Ford Liberty Third Brush System.

starting motor used with this equipment is of the four-pole series wound type with four field coils and two brushes as shown in the circuit diagram of Figure 278.

FORD LIBERTY SYSTEM

The standard Ford equipment includes a four-pole shunt wound generator with third-brush regulation as shown in Figure 279. The maximum output with a hot generator should be 11 to 12 amperes. The

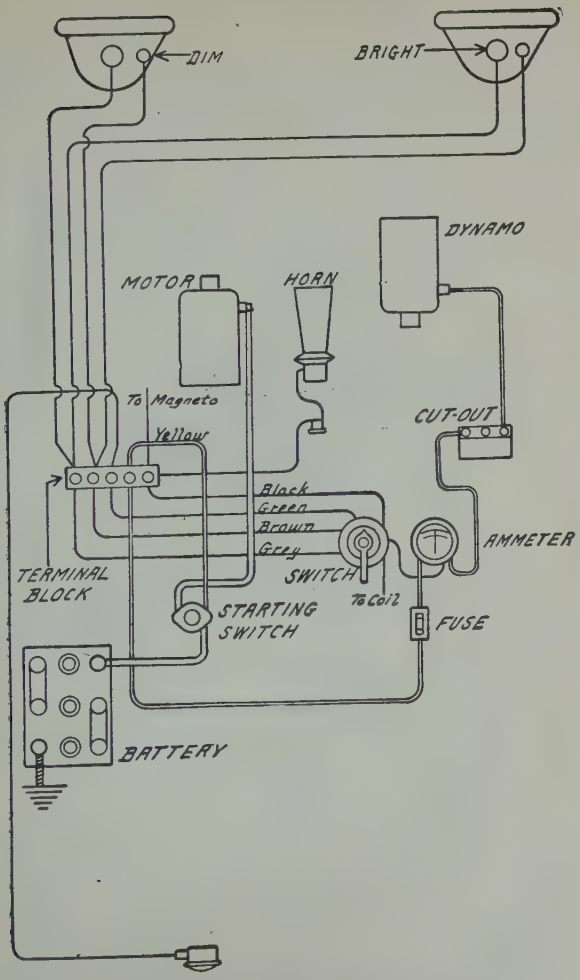


Figure 280.—Ford Wiring with Separate Cut-out.

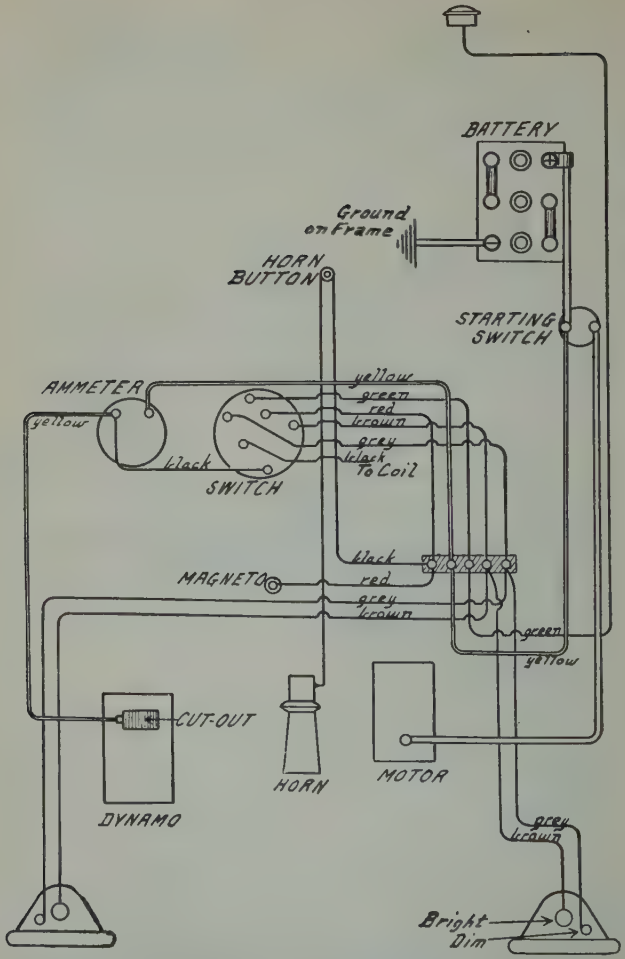


Figure 281.—Ford Wiring with Cut-out on Generator.

electromagnetic cut-out was mounted on the dash in a few of the earlier cars, which also had a main line fuse between the ammeter and the terminal block. The cut-outs are shown in Figure 123. The starting motor is of the four-pole, four-brush type with four

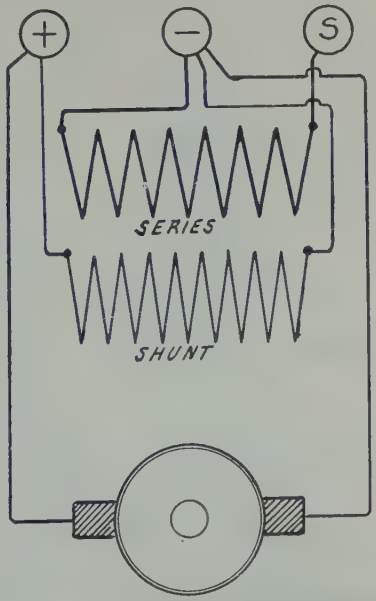


Figure 282.—Gray & Davis Constant Speed Generator.

field coils. The car wiring for this system is shown in Figures 280 and 281.

GRAY AND DAVIS

Some of the first Gray & Davis systems used compound wound generators as shown in Figure 282. This machine was driven at constant speed through

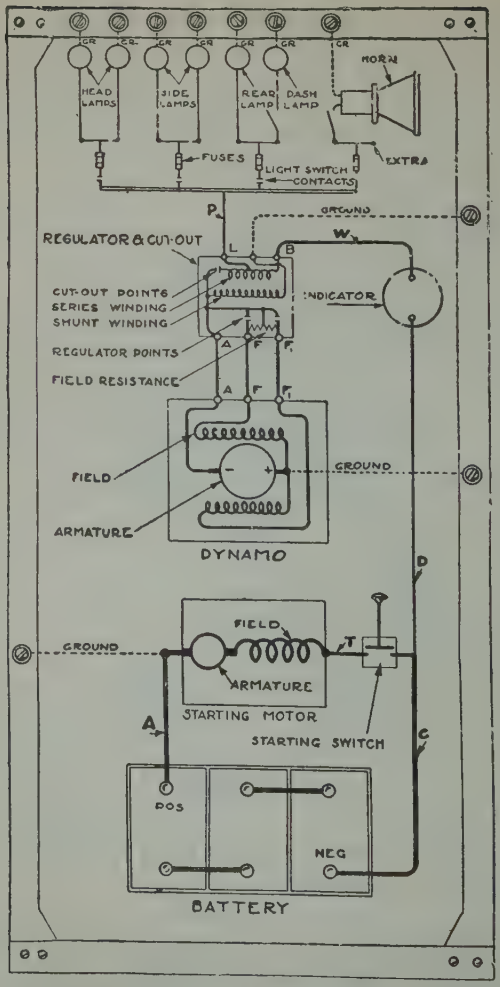


Figure 283.—Gray & Davis Constant Current System.

a slipping clutch governor like the one shown in Figure 96 or with a flat plate clutch governor. The regulation is shown and described in Figure 105. The output, with all lamps lighted, is between 8 and 10 amperes.

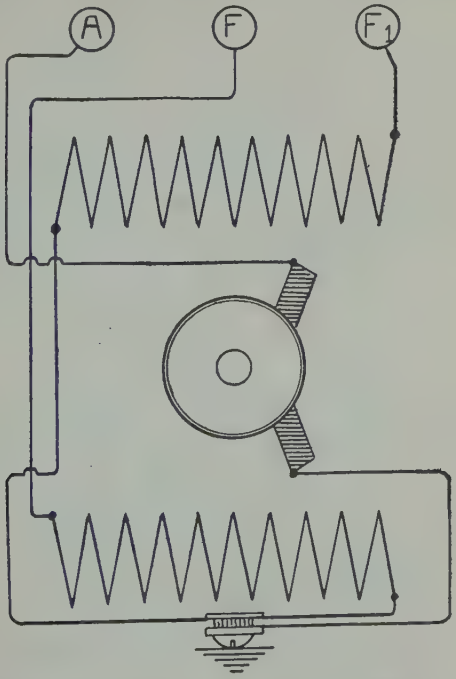


Figure 284.—Gray & Davis Generator for Constant Current.

Two-pole generators of the type shown in Figure 283 use the constant current vibrating regulator shown in Figure 85. The electromagnetic cut-out is combined in this controlling unit. The total output with

all lamps lighted is between 16 and 17 amperes maximum. The four-pole machine with two field coils, shown in Figure 284, uses this same regulator and gives a total output with lamps turned on of 16 to 18 amperes. The four-pole motor-generator shown in

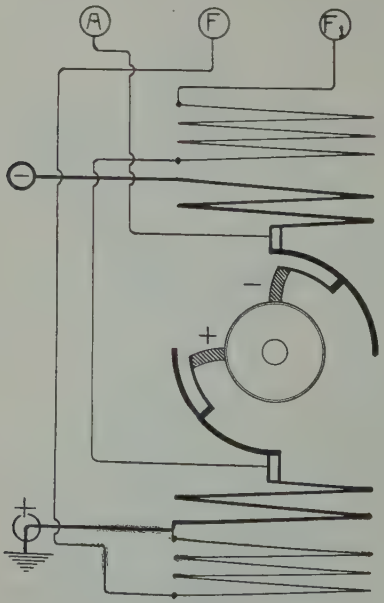


Figure 285.—Gray & Davis Motor-Generator.

Figure 285 uses a constant current vibrating regulator of a type similar to that used with the separate generators, except that the lamp load is not connected to the regulator and does not affect the output which is set for 8 to 11 amperes maximum.

The first Gray & Davis third-brush generators were of the four-pole, two field coil type shown in Figure 286. These machines were set for a maximum output of 15 amperes. The cut-out is mounted in the commutator end of the generator.

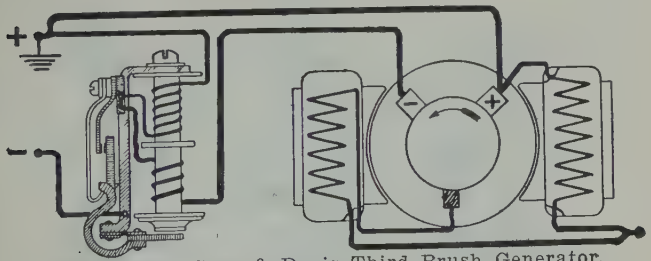


Figure 286.—Gray & Davis Third Brush Generator, Internal Cut-out.

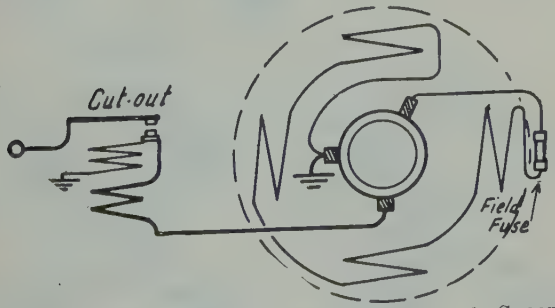


Figure 287.—Gray & Davis Round Third Brush Generator.

The latest third-brush Gray & Davis generators are of the type shown in Figure 287. These machines are of the four-pole type with four field coils. The four-inch sizes have a maximum output of 15 to 16 amperes and the five-inch sizes have a maximum of 16 to 18 amperes. The cut-out, shown in Figure 122.

is mounted on the generator, and a 5-ampere field fuse is on the commutator end of the machine.

Gray & Davis motors of the type shown at the left of Figure 288 are used with the constant speed gen-

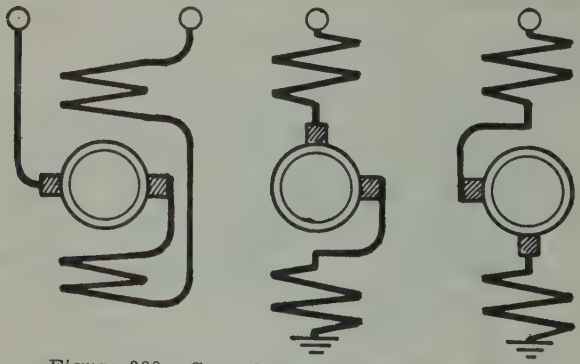


Figure 288.—Gray & Davis Starting Motors.

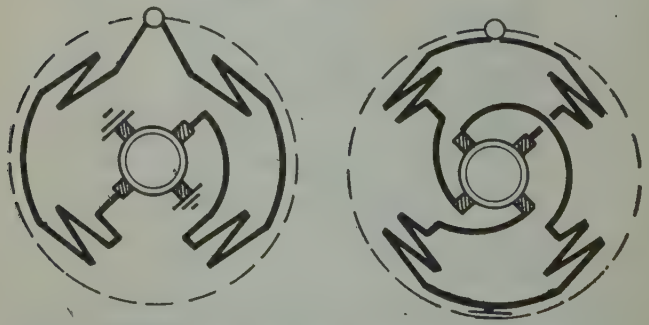


Figure 289.—Gray & Davis Round Frame Motors.

erators. Those of the type shown at the center and right hand side of Figure 288 are used with both constant current generators and two-field coil, third-

brush generators. The later third-brush generators are used with the starting motors shown in Figure 289.

LEECE-NEVILLE

All Leece-Neville separate unit generators are of

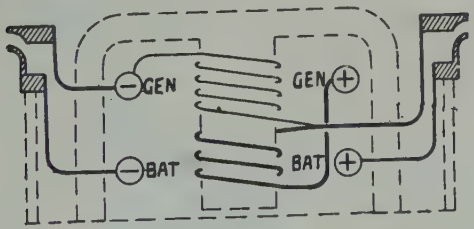


Figure 290.—Leece-Neville Two-pole Cut-out.

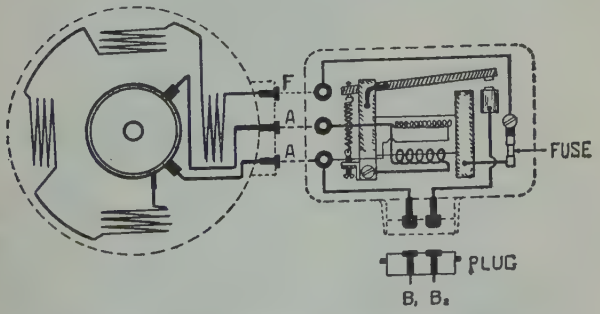


Figure 291.—Leece-Neville Generator and Cut-out.

the third-brush type with four poles and four field coils. The 6-volt machines have a maximum output of from 14 to 18 amperes and the 12-volt units from 8 to 12 amperes. All 6-volt machines have 5-ampere field fuses and 12-volt units have 10-ampere field fuses.

The electromagnetic cut-outs are mounted on the generator or carried as separate units. An early type of two-pole cut-out is shown in Figure 290. Generally

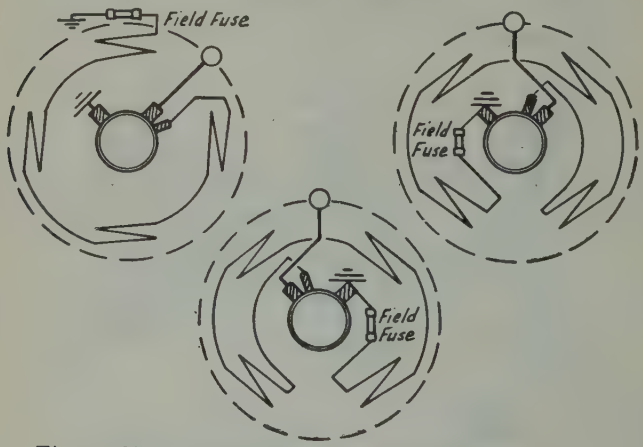


Figure 292.—Leece-Neville Third Brush Generators.

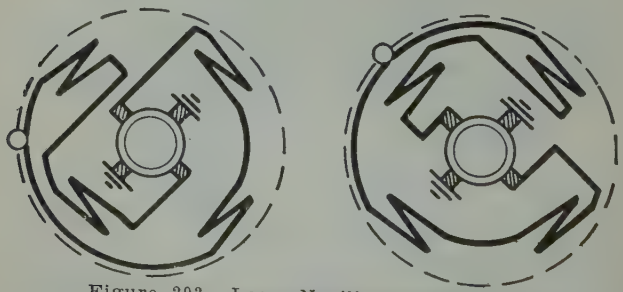


Figure 293.—Leece-Neville Starting Motors.

used types of generators are shown in Figures 291 and 292, while the starting motors of the four-pole series wound type are shown in Figure 293.

NORTH EAST

Older models of North East motor-generators are of the four-pole type with shunt and series windings. In the commutator end housing of the machine is a combined cut-out and constant current vibrating regulator as shown in Figure 79. The 12-volt machines are set for a maximum output of 6 to 7 amperes, while the 24-volt machines are set for a maximum of 4 to 6 amperes.

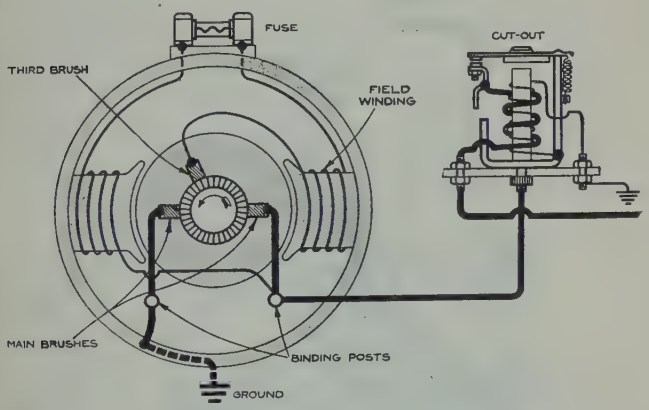


Figure 294.—North East Third Brush Generator and Cut-out.

The 12-volt motor-generator with third-brush regulation is shown in Figure 113. This machine has a maximum setting of 7 amperes with a charged battery. One machine of this type is built with the shunt coils on only two poles and the series coils on only the other two. The field fuse, when used, is of 10-ampere capacity. The electromagnetic cut-out is carried in the same housing with the starting switch.

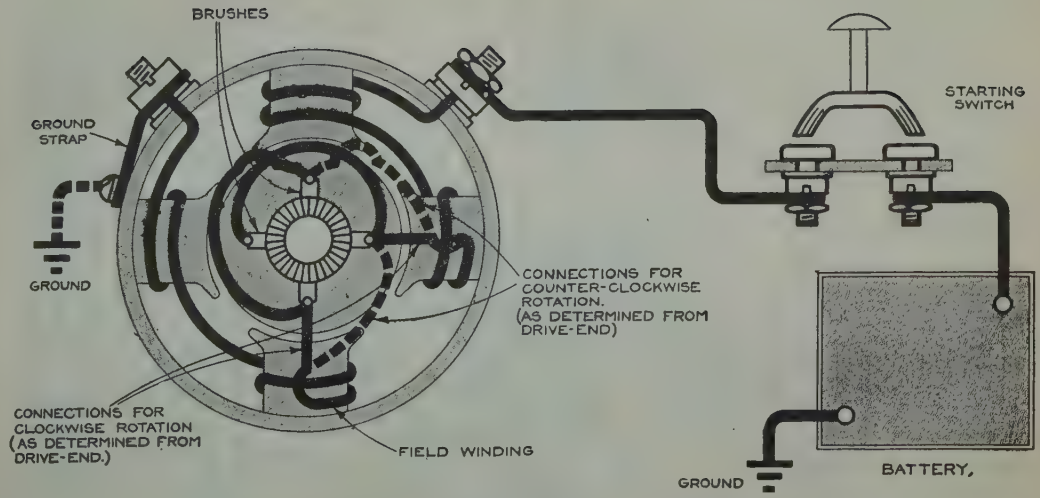


Figure 295.—North East Starting Motor.

A North East separate unit third-brush generator is shown in Figure 294, together with the electromagnetic cut-out used with it. This is a two-pole machine. The field fuse is carried on the generator housing and connected between the field coils. The maximum output of 6-volt machines is set at 16 amperes and of 12-volt machines at 11 amperes. The four-pole series wound starting motor used with this type of generator is shown in Figure 295.

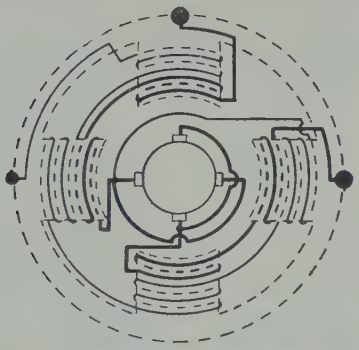


Figure 296.—Remy 12-volt Motor-Generator.

REMY

Among the first Remy generators were the two-pole third-brush machines of the type shown in Figures 67 and 118. These are 6-volt machines with a maximum output 12 to 16 amperes. The cut-out is mounted above the commutator on the generator. Another early type with a reversed series and a lamp load field winding is shown in Figure 71.

The circuits for a 12-volt Remy motor-generator with single armature and commutator are shown in

Figure 297.—Remy Double Deck Machine, Constant Current Type.

Figure 298.—Remy Double Deck Machine, Third Brush Type.

Figure 296. This machine uses a combined cut-out and vibrating constant current regulator of the type shown in Figure 299.

Double-deck motors and generators were made in constant current types as shown in Figure 297 and in third-brush types as shown in Figure 298. The constant current machines use a combined cut-out and vibrating regulator of the type shown in Figure 301. The 6-volt machines are set for a maximum of

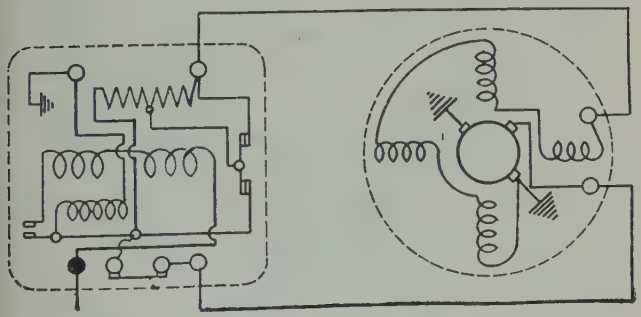


Figure 299.—Remy Constant Current Controller.

13 amperes and the 12-volt units for a maximum of 6 to 7 amperes. Except for being carried in the same frame or housing, these machines are separate generators and starting motors, the combination being made to simplify the drive connections between the electrical unit and the engine. The third-brush machines are all 6-volt types with a maximum output of 14 to 16 amperes.

There were a great many Remy generators of the four-pole type with three brushes, but with a constant current vibrating regulator as shown in Figure 76,

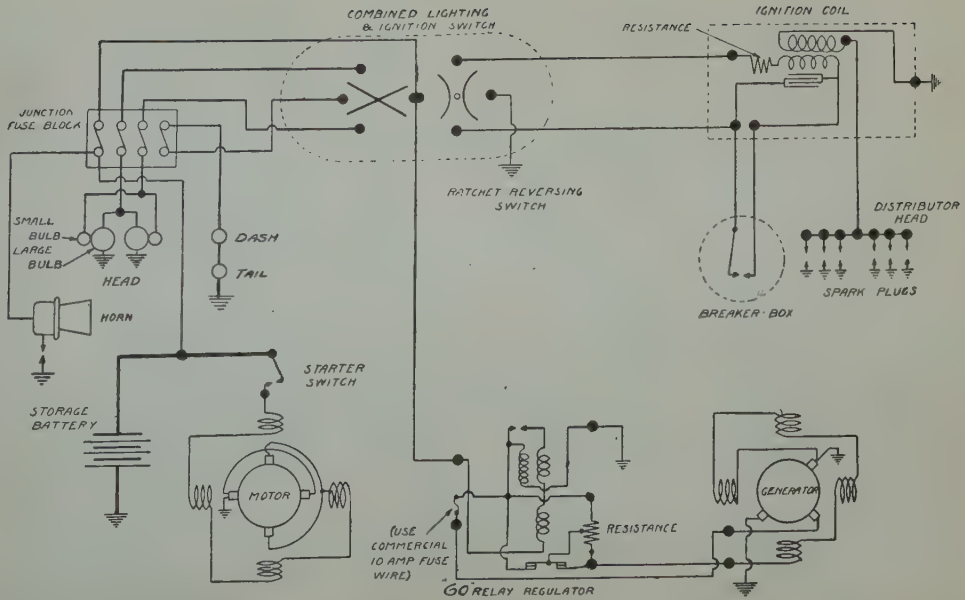


Figure 300.—Remy Constant Current System.

299, 300 and 301. These regulators are set to allow a maximum output of 13 to 15 amperes at 6 volts.

There have been a few Remy four-pole third-brush generators of the type shown in Figure 119,

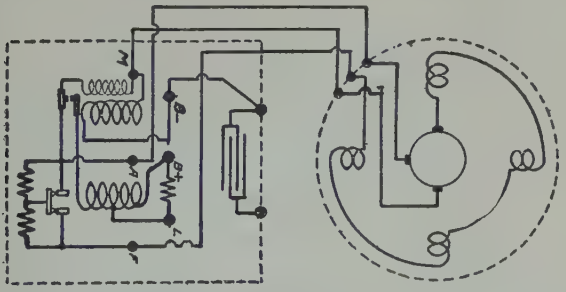


Figure 301.—Remy Constant Current Controller with Condenser.

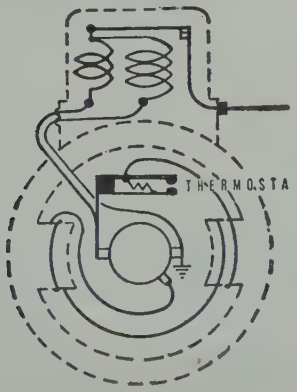


Figure 302.—Remy Third Brush Generator with Thermostat.

but the great majority of round third-brush generators have a thermostat control in addition to the third brush as shown and described in Figures 99

and 100, also in Figures 302 and 303. Depending on the type of machine, the maximum output with the thermostat contacts closed and the generator cold runs between 16 and 22 amperes. With the generator warmed up so that the thermostat opens, the rate drops according to the resistance on the thermostat. Most of the machines thus reduce their rate to between 6 and 9 amperes, while others cut it only to between 12 and 14 amperes with the thermostat open. Some of these machines have a field fuse between the thermostat and ground, although the thermostat

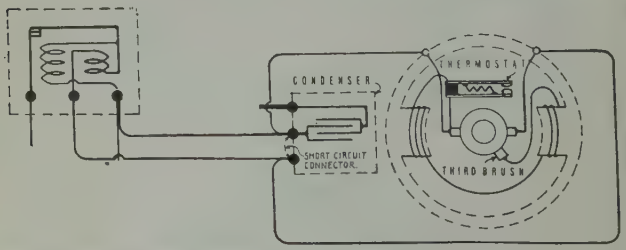
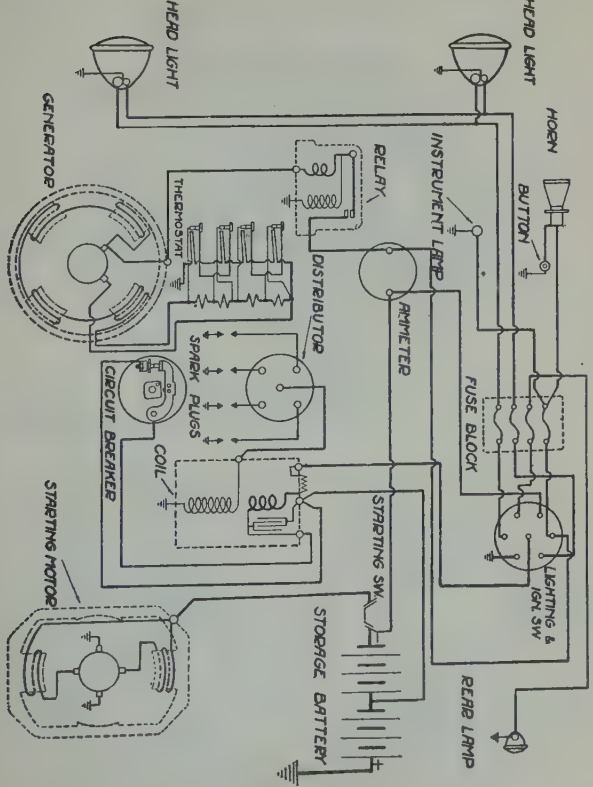


Figure 303.—Remy Thermostat Generator, Separate Cut-out.

resistance itself will act as a field fuse and burn out under the same conditions that would cause a fuse to open. Electromagnetic cut-outs of the type in Figure 124 are mounted on the generator or separately. One type of machine was made with four thermostats opening in succession, the third brush then being omitted. This generator is shown in Figures 101 and 304.

SIMMS-HUFF

The first Simms-Huff motor-generators were of the six-pole type shown in Figure 305. The machines


HEAD LIGHT
HORN
BUTTON
HEAD LIGHT
INSTRUMENT LAMP
RELAY
AMMETER
FUSE BLOCK
LIGHTING & IGN. SW
REAR LAMP
GENERATOR
THERMOSTAT
DISTRIBUTOR
SPARK PLUGS
CIRCUIT BREAKER
COIL
STARTING SW.
STORAGE BATTERY
STARTING MOTOR

that charge at 6 volts and crank at 12 volts use the commutating starting switch shown in Figure 188. They use a vibrating type of constant current

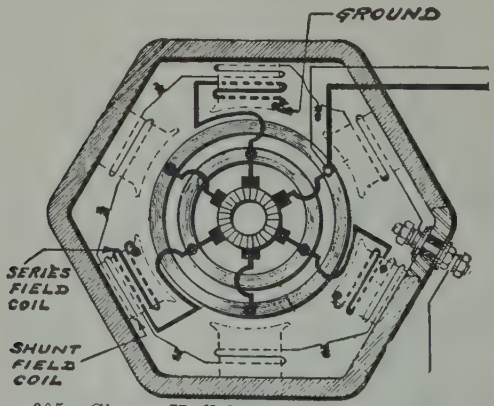


Figure 305.—Simms-Huff Motor-Generator for Constant Current.

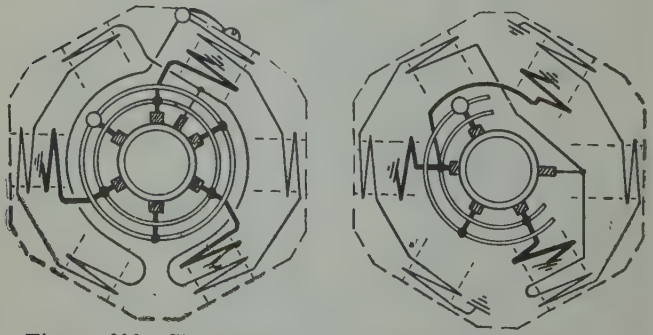


Figure 306.—Simms-Huff "Third Brush" Control Motor Generators.

regulator combined with the cut-out. With the button on the dash panel turned to "High," the maximum setting is for 15 amperes. Later these constant

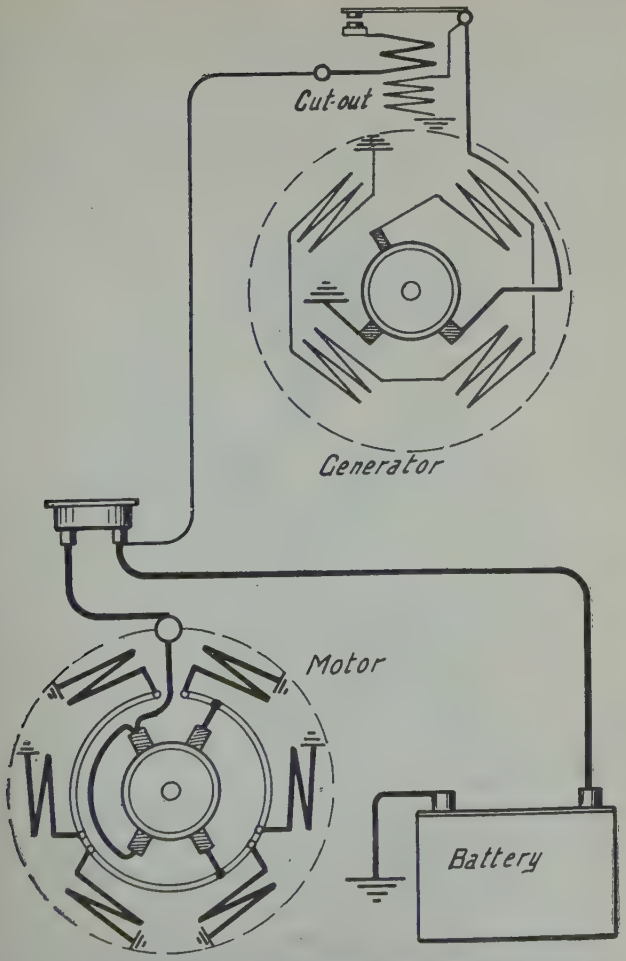


Figure 307.—Simms Third Brush Generator with Motor.

current motor-generators were built for 12-volts in both charging and starting, using a regulator as shown in Figure 83 set for a maximum of 7½ amperes.

The later motor-generators are of the third brush type, as shown in Figure 306, one style having five brushes, the other having seven. The maximum out-

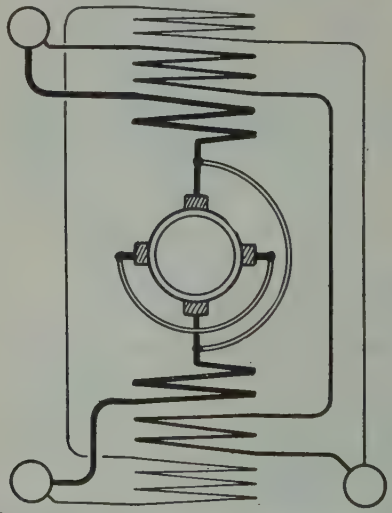


Figure 308.—Splitdorf Reversed Series Motor-Generator.

put is set at 10 to 11 amperes at 12 volts. An electro-magnetic cut-out is carried on the motor-generator.

The Simms separate generator and motor are shown in Figure 307. The generator is a four-pole machine of the third brush type with a cut-out mounted on top. The maximum output is between 15 and 17 amperes. The starting motor is a six-pole machine with four brushes and six field coils

SPLITDORF

The Splitdorf motor-generator using reversed series regulation is shown in Figure 308. The cut-out used with this machine is shown in Figure 111. Some of these machines generate at 6 volts and crank at 12 volts, others both generate and crank at 12 volts. For the 6-12 volt system the starting switch connections are shown in Figure 187. The maximum output of the 6-volt machines is from 13 to 15 amperes and for the 12-volt machines from 7 to 8 amperes.

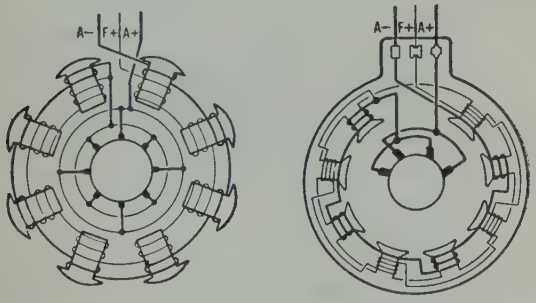


Figure 309.—U. S. L. External Armature and Internal Armature Motor-Generators for Constant Current.

A constant voltage Splitdorf generator with a cam regulator is shown in Figure 98. This machine is used without a battery, the voltage control being sufficient to provide lighting current at proper pressure at varying speeds.

U. S. L.

The motor-generators made by the United States Light and Heat Corporation are mounted directly on the engine crankshaft together with the fly-

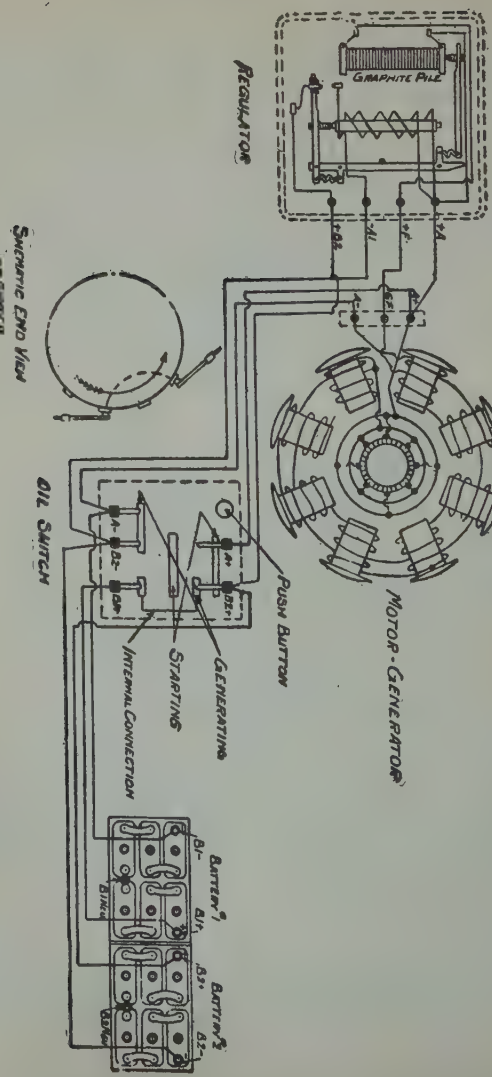


Figure 310.—U. S. L. Constant Current System.

wheel, as shown in Figure 171. In some constructions the armature rotates outside the field coils, this construction being shown in Figure 172 and at the left in Figure 309. Other types have an internal armature and external fields as shown at the right in Figure 309.

The early machines with an internal armature charge at 6 volts and crank at 12 volts; with the external armature they charge at 12 volts and crank

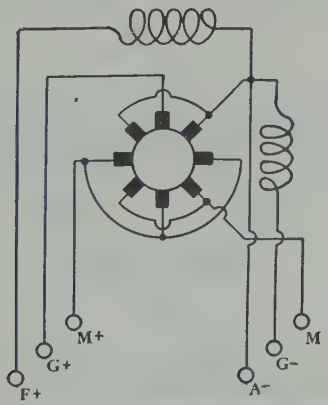


Figure 311.—U. S. L. 12-24 Volt Motor-Generator.

at 24 volts. These machines use the carbon disc current regulator shown in Figure 310 and allow a maximum of 18 amperes on 6-volt charging and 10 amperes on the 12-volt.

Later machines use a reversed series regulation as shown in Figures 152 and 311, charging at 12 volts and cranking at 24 volts. The maximum charge rate is about 12 amperes. The last machines operating at 12 volts for both charging and cranking are shown

in Figure 312. The maximum output is about 12 amperes. A separate electromagnetic cut-out carries either a 5-ampere or 6-ampere field fuse.

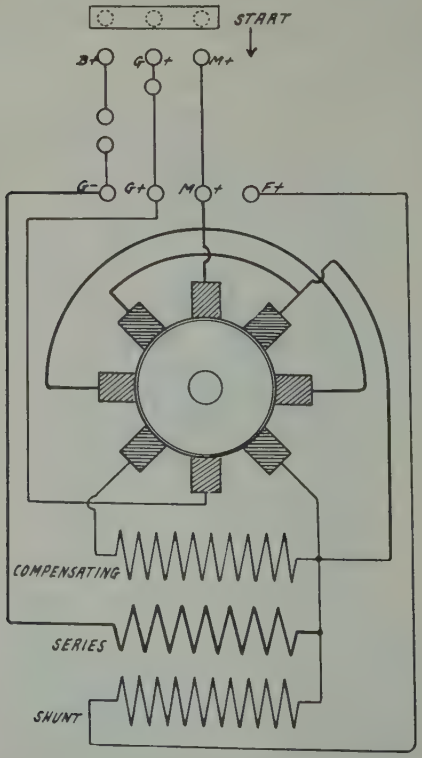


Figure 312.—U. S. L. 12-12 Volt Motor-Generator.

WAGNER

The earliest Wagner motor-generator system is shown in Figure 189. This machine has one arma-

ture with one commutator at each end and four brushes for each commutator. It uses a drum switch allowing 12 volts for cranking and 6 volts for charging and lighting. Regulation is by third-brush action with a maximum output of about 10 amperes.

Later Wagner equipment uses a separate generator with four brushes, as shown in Figure 313, one of them acting as a regulating or "third" brush. An electromagnetic cut-out may be mounted on the generator or as a separate unit. With a charged battery, the maximum setting for 6-volt machines is 16

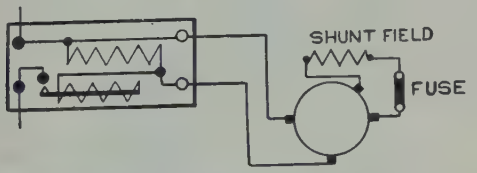


Figure 313.—Wagner Four Brush Generator with Cut-out.

to 18 amperes, and for 12-volt types from 8 to 9 amperes.

Present Wagner equipment consists of third-brush generators, separate electromagnetic cut-outs, shown in Figure 125, and four-pole starting motors of the general type, shown in Figure 314. The setting of these generators is made between 14 and 16 amperes with a charged battery.

WARD LEONARD

Combined constant current regulators and electromagnetic cut-outs of Ward Leonard make are used on many makes of electrical equipment. The type "E" control is shown in Figure 84. On 6-volt

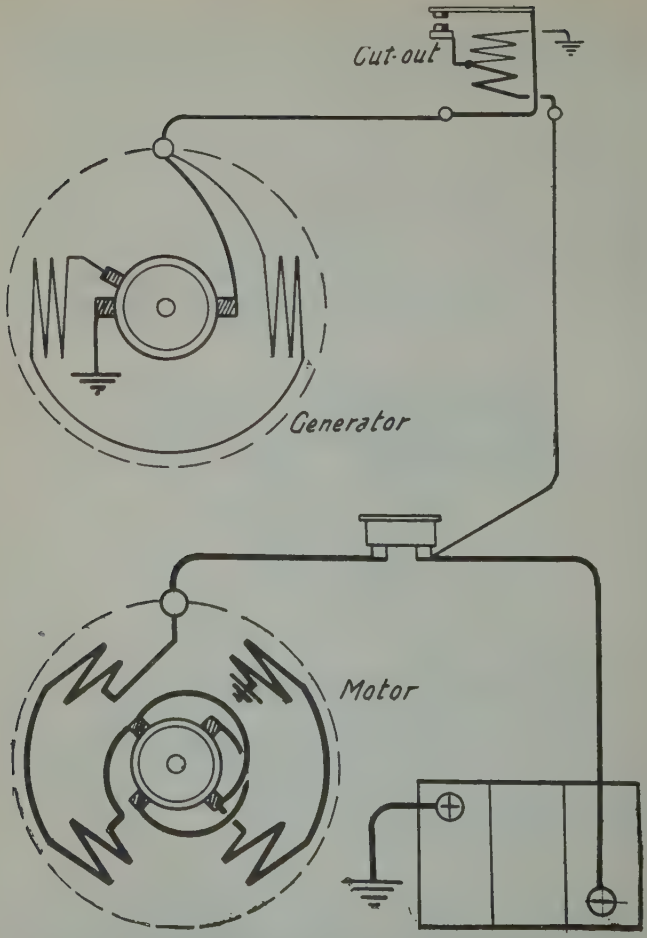


Figure 314.—Wagner Third Brush Generator System.

systems its setting is for 10 amperes maximum. The type "CD" single step instrument is shown in Figure 315. It is set for 12 amperes maximum in most cases. In Figure 82 is shown the type "CD" two-step controller which allows a maximum of 8 to 10 amperes at 12 volts. Figure 116 shows the "CC" controller, which should be set for a maximum of 10 amperes with a charged battery. Figure 40 shows a Ward Leonard generator.

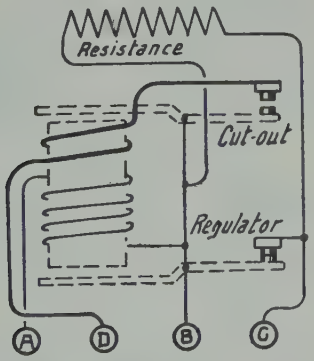


Figure 315.—Ward Leonard "CD" One-step Controller.

WESTINGHOUSE

The first Westinghouse generators were of the reversed series type made with an ignition coil, breaker and distributor in the generator housing as shown in Figure 316, or without the ignition as shown in Figure 73. The lighting line is connected to one end of the series winding and the battery line to the other, so that current going directly from generator to lamps does not pass through the series coil, consequently does not oppose the shunt field and allows

an increased output with the lamps lighted. The output on 6-volt machines at ordinary driving speeds is between 10 and 12 amperes, except on a few machines, which run up to 15 or 16 amperes. On 12-volt units the output runs between 7 and 8 amperes at usual driving speeds. These rates are with the lamps turned off.

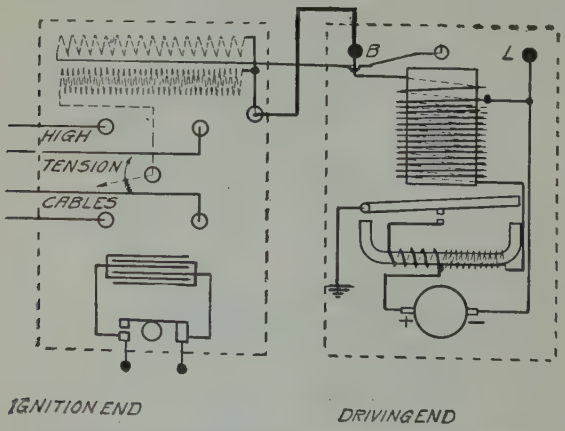


Figure 316.—Westinghouse Reversed Series Ignition-Generator.

Other Westinghouse generators using this same scheme of reversed series regulation are of the four-pole type, as shown in Figure 317. These machines, like the two-pole types, have an electromagnetic cut-out on the generator. The maximum output on the four-pole types runs around 15 amperes at 6 volts.

There are two types of Westinghouse constant voltage generators, one with the combined voltage regulator and cut-out built into the generator, as in Figure

318, the other with a generator of the type shown in Figure 319, which uses the voltage regulator and cut-out shown in Figures 90, 91 and 92. The voltage regulator settings are made to give 15 amperes at

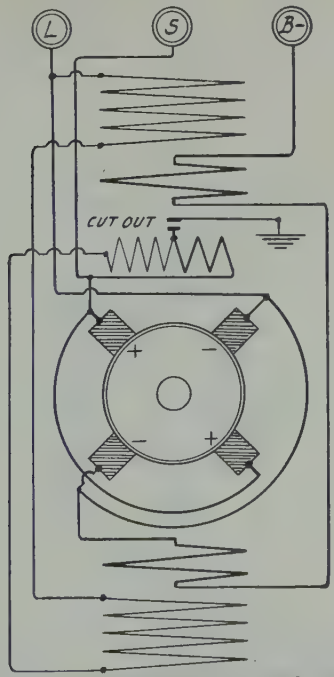


Figure 317.—Westinghouse Four-pole Reversed Series Generator.

6 8/10 volts on most of these machines. The constant voltage feature gives low rates, 5 to 7 amperes, with a fully charged battery and high rates, 15 to 16 amperes maximum, with a discharged battery. The

setting is made for 12 amperes on the 251R machines and for 20 amperes on the 781R and 782R machines.

There is one 12-volt Westinghouse motor-generator, shown in Figure 320. This machine uses third-brush

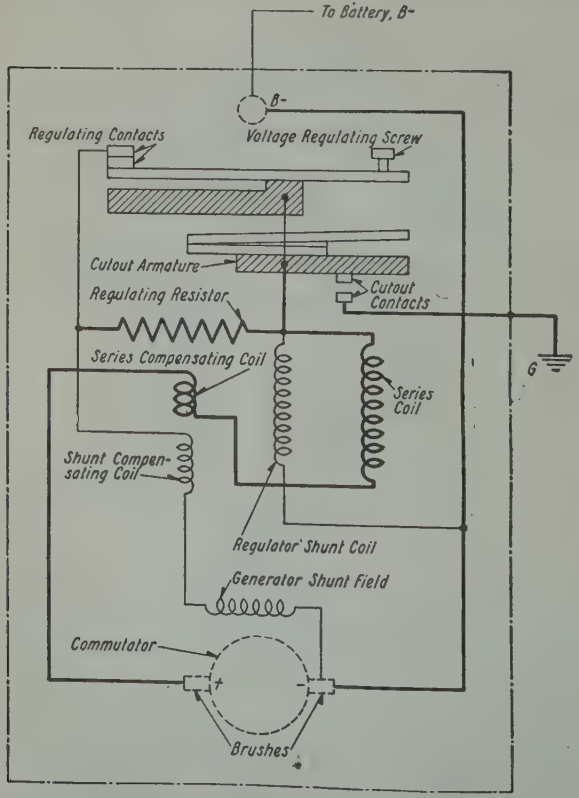


Figure 318.—Westinghouse Constant Voltage Generator with Internal Controller.

regulation and allows a maximum output of 9 amperes. These motor-generators use the cut-out mounted in the starting switch, as shown in Figures 117 and 182.

The most generally used Westinghouse equipment at present is of the third-brush type, shown in Figure 321. These are four-pole shunt wound machines with four field coils and two brushes. They carry a

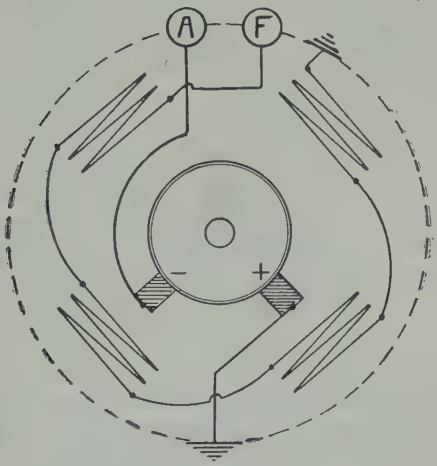


Figure 319.—Westinghouse Generator for Constant Voltage.

5-ampere field fuse. The electromagnetic cut-out may be carried inside the generator as shown in Figures 321, or mounted as a separate unit. With a separate cut-out the generator is similar to the construction shown in Figure 319, and the field fuse is generally carried on the cut-out. The output setting of these machines varies with the type, but is generally between 14 and 16 amperes for 6-volt machines and

Figure 320.—Westinghouse Third Brush Motor-Generator.

Figure 321.—Westinghouse Third Brush Generator, Internal Cut-out.

about 10 amperes for 12-volt types. This setting may, however, be excessive for some types, which run as low as 10 to 12 amperes maximum.

Westinghouse automatic starting switches and automatic starting pinion shifts are shown in Figures 186, 195 and 196.

GENERATOR OUTPUT RATES
(MAXIMUM SETTINGS)

Maker and Type	*Regulation	Voltage	Amperes
Adlake			
	Plunger mag., CC..	6	15–20
Allis-Chalmers			
Motor-generator	Vibrator, CC.....	6	10–12
Aplco			
Motor-generator	Stop charge, CV..	6–30	22
Generator A-2½	Carbon disc, CC..	6	10
Third-brush generator	3d brush.....	6	8
Atwater Kent			
Third-brush system	3d brush.....	6	12–15
Auto-Lite			
Permanent magnet	Constant speed, CV	6	13
Single coil generator	Reversed series...	6	16
Square frame, GB, GC	Reversed series...	6	14–15
Square frame, GD, GG	Reversed series...	6	12
Square frame, GH	3d brush.....	6	16
Round frame	3d brush.....	6	16–17
Bijur			
Constant voltage	Vibrator, CV.....	6	5–10
Cut-out inside	3d brush.....	6	14–16
Outside cut-out	3d brush.....	6	12–15
Motor-generator	3d brush.....	12	7–9
Bosch			
"De Luxe" system	Carbon-mica, CV.	12	8–10
Standard system	Reversed series...	6	12–16
Standard system	Reversed series...	12	6–9
Third-brush types, 4-inch	3d brush.....	6	10–12
Third-brush types, 5-inch	3d brush.....	6	14–16
Briggs-Nash			
Ignition-generator	Vibrator, CC.....	6	17
Deaco			
Permanent magnet	Field relays.....	6	8–12
Motor-generator	Reversed series...	8	18
Third-brush	3d brush.....	6	12–15

* CC. indicates Constant Current; CV indicates Constant Voltage.

Maker and Type	*Regulation	Voltage	Amperes
Delco			
Motor-gen., 6–24 volt	Rev. series, meter.	6–24	18–22
Motor-gen., single coil	Mercury well, CV.	6	10
Motor-gen., rebuilt	Reversed series...	6	20
Motor-gen., Junior	Reversed series...	6	15–16
Motor-gen., governor	Resistance spool..	6	18–22
Motor-gen., regulator	Vibrator, CC.....	6	16
Motor-gen., 3d brush	3d brush.....	6	15–20
Generator, single coil	3d brush.....	6	16–20
Round generators	3d brush.....	6	14–18
Voltage control	Vibrator, CV.....	6	7¾ v.
Voltage control	Vibrator, CV.....	12	15 v.
Motor-gen., round frame	3d brush, thermo.	6	15–16
Detroit Ward Leonard			
Motor-generator	Vibrator, CC.....	6	12
Separate generator	Vibrator, CC.....	6	10
Disco			
Motor-generator	Vibrator, CC.....	12	10
Separate units	Reversed series...	6	15
Separate units	Reversed series...	12	6–8
Separate units	Vibrator, CC.....	6	10
Dyneto			
Six-pole, motor-generator	Reversed series...	12	10
Six-pole, motor-generator	3d brush.....	12	12–14
Generator, VA	3d brush.....	12	12–24
Generator, C. types	Vibrator, CC.....	6	10
Round motor-generator	3d brush.....	12	12
Eisemann			
Magneto-generator	Reversed series...	6	12
Magneto-generator	Reversed series...	12	6
Electro			
Motor-generator	Shunt field only..	6–24	30
Entz			
Motor-generator	Reversed series...	18	13
Esterline	Reversed series...	6	10–12
Fisher	Reversed series...	12	6–7
Ford			
Liberty system	3d brush.....	6	11–12

*CC. indicates Constant Current; CV indicates Constant Voltage.

Maker and Type	*Regulation	Voltage	Amperes
Genemotor			
Motor-generator	3d brush	12	7–8
Gray & Davis			
Constant speed type	Governor, CV	6	8–10
Current regulator types	Vibrator, CC	6	16–17
Motor-generator	Vibrator, CC	6	8–11
Square frame generator	3d brush	6	15
Round generators, 4-inch	3d brush	6	15–16
Round generators, 5-inch	3d brush	6	16–18
Heinze			
Double deck type	Vibrator, CC	6	10
Separate units	Reversed series	6	12
Jesco			
Motor-gen., dash control	Vibrator, Rev. Ser.	8–16	12–13
Motor-generator, regulator	Vibrator, Rev. Ser.	6	12–15
Tandem machine	Vibrator, Rev. Ser.	6	12–15
Kemco			
Fan type, 2½-inch	Vibrator, CC	6	12
Fan type, 3-inch	Vibrator, CC	6	20
Leece-Neville			
Square frame	3d brush	12	12
Round generators	3d brush	6	14–18
Round generators	3d brush	12	8–12
National			
Ignition-generator	Reversed series	6	17
North East			
Motor-generator, A	Vibrator, CC	8–16	6
Motor-generator, B	Vibrator, CC	12	7
Motor-generator, B	Vibrator, CC	16	6
Motor-generator, B	Vibrator, CC	24	5
Motor-generator, D, E	Vibrator, CC	12	7
Motor-generator, D, E	Vibrator, CC	24	5
Motor-generator, G	3d brush	12	7
Separate unit	3d brush	6	16
Separate unit	3d brush	12	11
Remy			
Generators, M, MJ	Reversed series	12	6
Ignition-generators	3d brush	6	14–16

* CC. indicates Constant Current; CV indicates Constant Voltage.

Maker and Type	*Regulation	Voltage	Amperes
Motor-generators	Vibrator, CC	12	8
Double-deck, regulator	Vibrator, CC	6	13
Double-deck, regulator	Vibrator, CC	12	7
Double-deck	3d brush	6	14–16
Generators, regulator	Vibrator, CC	6	13–15
Generator, 3d brush	3d brush	6	12–13
Thermostat control	3d brush	6	16–22
Generator, 238	Thermostat only	6	18
Rushmore			
Generator	Iron wire, Rev. Ser.	6	14–17
Generator	Iron wire, Rev. Ser.	12	7–9
Simms-Huff			
Motor-generator, 6-12-volt	Vibrator, CC	6–12	15
Motor-generator, 12-volt	Vibrator, CC	12	8
Motor-generator, SMS	3d brush	12	10–12
Simms			
Separate units	3d brush	6	15–17
Splitdorf			
Generators	Vibrator, CC	6	10
Motor-generator	Reversed series	6–12	13–15
Motor-generator	Reversed series	12	7–8
Separate generator	Cam control, CV	6	7–8
U. S. L.			
External regulator	Carbon disc, CC	6–12	18
External regulator	Carbon disc, CC	12–24	10
Inherent regulation	Reversed series	12	12
Vesta			
Permanent magnet	Governor	6	5–6
Wagner			
Motor-generator	3d brush	6–12	10
Generators, 4-pole	3d brush	6	16–18
Generators, 4-pole	3d brush	12	8–9
Generators, 2-pole	3d brush	6	14–16
Ward Leonard	Vibrator, CC	6	10
Wells			
Motor-generator	Vibrator, CC	6	10

* CC. indicates Constant Current; CV indicates Constant Voltage.

Maker and Type	*Regulation	Voltage	Amperes
Westinghouse			
Square frame, 2-pole	Reversed series	6	10–12
Square frame, 2-pole	Reversed series	12	7–8
Square frame, 4-pole	Reversed series	6	15
Square, voltage control	Vibrator, CV	6	15
Round, voltage control, 400	Vibrator, CV	6	15
Round, voltage control, 700	Vibrator, CV	6	20
Round, 3d brush	3d brush	6	14–16
Round, 3d brush	3d brush	12	10
Cam regulated	Cam, CV	6	12
Motor-generator	3d brush	12	9

* CC. indicates Constant Current; CV indicates Constant Voltage.

PART III

AUTOMOBILE IGNITION

AUTOMOBILE IGNITION

CHAPTER I

ELECTRIC IGNITION

The object of the whole ignition system of an automobile is simply the production of a small spark about a fiftieth of an inch in length in the cylinder of the engine, yet the parts required for producing this spark are among the most interesting and highly developed of all the units that go to make up the completed car.

Many methods of ignition have been used, not all of them electric, but all except one, the jump spark system, have disappeared. This remaining system makes use of a current of electricity having such high pressure or voltage that it is capable of passing through the highly compressed gas in the cylinder and across the space between two metallic points as shown at C in Figure 1. This passage of current produces an electric spark of great heat and from this spark the inflammable mixture of gasoline vapor and air or the vapor of any other fuel is ignited and the resulting combustion produces the pressure and power that operates the car.

Early types of engines made use of fireproof tubes maintained at incandescence by an external flame

and when the gas in the cylinder was allowed to come into contact with these tubes, ignition resulted. This type is shown at A in Figure 1. Certain forms of engines in use today ignite the combustible gases by the heat resulting from high compression, the Diesel engine being the best known example of this method.

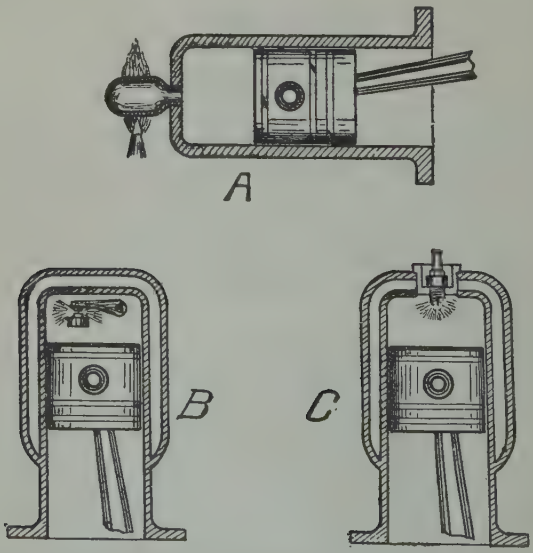


Figure 1.—Three Types of Ignition. A: Hot Bulb. B: Make and Break. C: Jump Spark.

Stationary engines now in use, and early types of automobile engines use the "make and break" system of ignition shown at B in the illustration. With this method a current of low voltage and large volume or amperage normally passes from a stationary contact mounted within the combustion space

of the engine cylinder to a movable contact likewise carried inside of the cylinder. At the proper instant these contacts are caused to separate by external mechanism and the result of this interruption of the flow of current is a hot spark at the contacts. While the study of these obsolete methods would be interesting, it would be of no practical usefulness because cars using them have long since passed out of use, therefore they are not considered in the following pages.

Modern forms of jump spark ignition may be divided into three classes. The oldest class, and at present the least used, is that known as the battery system. This form was popular from the inception of the present type of gasoline car and retained its position of importance until about the year 1907 or 1908. At that time the magneto was introduced on a large number of cars that had not previously carried it because of the high cost of this instrument. From that time until about 1914 the magneto dominated the field almost to the exclusion of other forms. With the advent of electric starting and lighting came the new type of battery ignition that draws its current supply from the lighting and starting battery and from the lighting dynamo. At the present time, while the magneto has its strong supporters and is found on a great number of cars, the battery systems are found in greater numbers than are magnetos.

TIME OF IGNITION

Engine Cycle.—The instant at which ignition is effected is an important point in the cycle of operations through which the internal combustion engine

passes. Those familiar with this class of work know that the type of engine usually employed makes use of the four cycle principle in which four strokes, as shown in Figure 2, are required to perform the necessary operations. The first stroke is called the inlet, during which fresh gas is drawn into the cylinder and the second is the compression during which the gas is forced into the combustion space, and at the

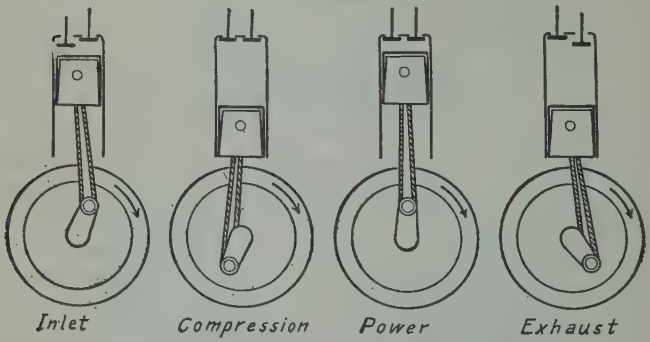


Figure 2.—Strokes of a Four Cycle Engine.

end of which comes the ignition point or time at which the compressed gas is ignited. During the third stroke of the piston the burning gas expands and on the fourth and final stroke the spent charge is exhausted.

It is at some time during the compression stroke, or at the end of this stroke, that the gas must be ignited. The exact instant at which the spark occurs depends on several factors, but in all cases the object sought is that the entire charge will be fully aflame and at the point of greatest pressure when the piston

has reached the top of its stroke and is ready to descend on the power stroke.

The space occupied by the gas when compressed is of considerable volume but in the usual design it is only at one small point in this space that the ignition spark takes place. Rapid though the travel of the flame may be, an appreciable time is required for the whole charge of gas to become fully ignited and to reach its point of greatest pressure. The ignition flame starts in the gas immediately surrounding the spark and finally reaches the farthest points of the combustion space in the cylinder.

During this time of flame travel, the piston of the engine is moving with greater or less rapidity up or down in the cylinder, the piston speed depending on the number of revolutions that the crank shaft is then making in a given length of time. In order that the engine may develop the greatest possible power from the amount of fuel being used it is necessary that the gas be ignited at such time as will insure maximum pressure immediately after the piston starts on its down stroke.

Should the gas become fully ignited while the piston is still traveling upward on the compression stroke, a strong downward force would be exerted, tending to retard the speed of the engine and greatly reducing the power output.

On the other hand, should ignition fail to take place until the piston had reached the top and again started on its downward stroke, the gas would have lost much of its power possibilities because of the reduced degree of compression. The power and pressure of the burning gas is in direct proportion to the compression pressure of the gas when ignited

and the cylinder is so designed that the stroke of the piston causes the correct degree of compression. If ignition takes place too late, part of this compression pressure is lost with a resulting lowering of the power output and economy.

When the piston is traveling very slowly, as for instance, in the cranking operation, the gas will fully ignite before the piston has traveled more than a very little of its stroke and the spark can safely take place practically at the same instant that full ignition is desired, this being when the piston is at the top of its stroke.

If the time at which the spark passes is not changed according to the engine speed, and if the engine is then run very fast, full ignition will not take place until the piston has started on its down stroke with the results already outlined.

With an engine having a stroke of 5 inches and running at 2,000 revolutions a minute, the piston speed will be 20,000 inches a minutes or 333⅓ inches each second. In 1/100 part of a second the piston will have passed from its uppermost position, 3⅓ inches down on its stroke and if the rate of flame travel requires this 1/100th of a second to fully ignite the gas the power stroke will be two-thirds completed before full ignition takes place. To cause complete firing of the charge and full generation of pressure to take place with the piston at the top of its stroke, it is necessary that the spark pass earlier and earlier during the compression stroke as the engine speed increases, so that the full force of the burning gas may be available at the desired time. This change in time of ignition is effected in various ways which will be described in detail.

With the engine running fast the stroke is made to occur earlier in the compression stroke and the spark is then said to be advanced. For cranking and for slow running, the spark is caused later, being at or near top center, and the spark is then said to be retarded.

SPARK CONTROL

In order to cause the electric spark to pass through the inflammable mixture at such time as to produce complete ignition of the charge when required, a majority of systems provide means for altering this time to correspond with engine speed. All of the systems in which such means are provided are included in the class known as variable spark ignition systems. In some of these types the spark timing is controlled by the driver and this form is given the name of hand or manual control. In others the timing of the spark is changed mechanically by some form of governor and these are known as automatic advance systems.

Many magneto installations have been made without provision for altering the time at which the spark passes and this type goes by the name of set spark ignition. With set spark ignition the permanent advance is made sufficient to care for all average conditions of operation.

While the set spark method causes ignition to commence considerably before the piston reaches top center, no ill effects are encountered even while cranking the engine because of the fact that when the cranking is done at speed sufficiently high to cause the magneto to generate current enough for a spark,

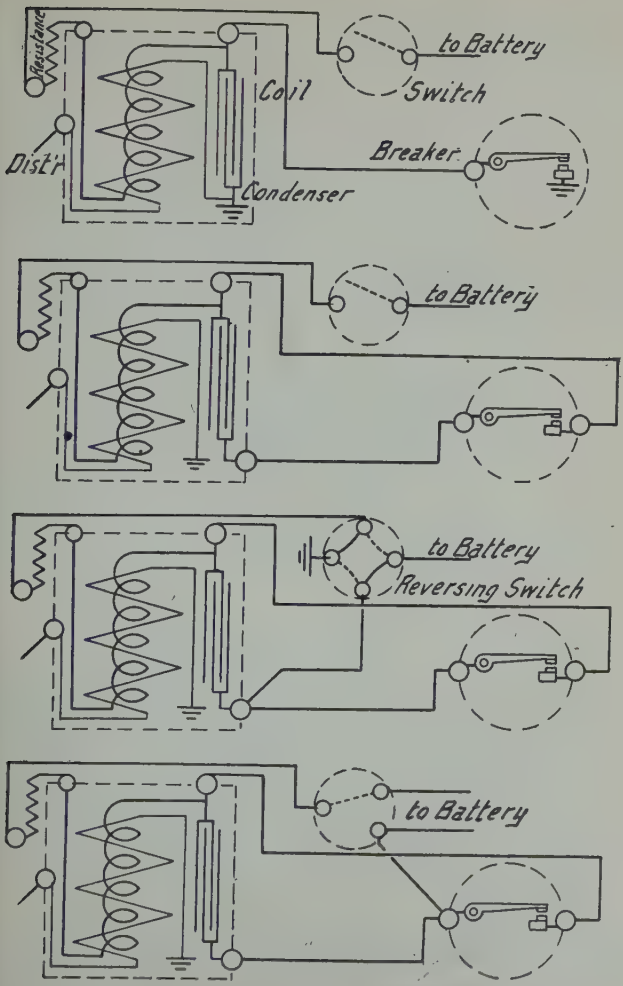
the flywheel is traveling fast enough to require such an advance and the power impulse takes place as usual. Set spark ignition has the advantage of simplicity but is limited in the range of engine speed over which it is capable of giving maximum power.

THE INDUCTION COIL

In order to produce a spark within the cylinder of the engine it is necessary that the electric current jump across a small gap which is inside the cylinder and surrounded by the gaseous mixture. A current of extremely high pressure or voltage is required in order to pass across this gap because the resistance to be overcome is so great that no ordinary voltage has any effect. The pressure of the current from any of the primary sources used for ignition is never more than from six to fifty volts, but this current of low voltage is of comparatively great volume or amperage, and is used to produce another current having voltage sufficiently high to pass across the gap, through the mixture, and in so doing produce the heat of the electric spark.

The required high voltage or high tension current is secured by induction from the primary current which is of comparatively low voltage as received from the electrical source.

Should the core of an electro-magnet be extended this extended portion would, of course, have the same magnetic qualities as would the balance of the magnet. A conductor coiled around the extended core would then be in the magnetic field of the electro-magnet and would be influenced by changes of strength in the magnetic field.



Figures 3, 4, 5 and 6.—Ignition Circuits with Condensers in Coils.

It has been found that any change in the strength of a magnetic field within which is a coil of wire will cause electric currents to be induced in the coil, the strength of these currents depending on the intensity of the magnetism, and on its degree of change.

In actual practice the second coil of wire in which is to be induced the high voltage current is generally wound around the outside of the primary coil already on the electro-magnet. The double coil with its core is then called an induction coil. The winding through which passes the current from the source of electri-

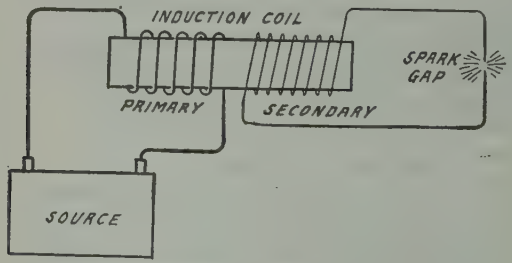


Figure 7.—Principle of the Induction Coil.

city is called the primary or low tension winding and the coil wound outside the primary is called the secondary or high tension winding. The current which passes through the primary winding is called the primary current and that which passes through the secondary winding is called the high tension or secondary current, the relation of these parts being shown in Figure 7.

When a current of comparatively low voltage is passed through the primary winding of the induction coil there is a current generated in the secondary

winding. This current which is induced by completion of the primary circuit is not of sufficient strength to cause a spark in the cylinder.

When, however, the circuit through the primary winding is broken and the current ceases to flow there is a very powerful action in the coil and a high tension current is induced in the secondary winding with sufficient voltage to cause the current to pass across the spark gap and ignite the mixture.

The pressure or voltage of the secondary current is greater than the voltage of the primary current in proportion to the number of turns of wire in the secondary winding as compared with the number of turns in the primary winding, less the loss due to the transfer of energy. The primary current is of low voltage and rather high amperage, while the secondary current is of extremely high voltage and very low amperage. The primary winding consists of a small number of turns of large size wire and the secondary winding consists of a great number of turns of fine wire.

The induction coil is usually called a spark coil or else a transformer coil. The name transformer coil is not, strictly speaking, the correct one because a transformer coil is used to produce a low voltage current from one of high voltage. Usage has made the name transformer coil apply to the induction coil used in ignition so that this name is now accepted.

CURRENT SOURCES

There are four commonly used sources of current for ignition. The source found on cars equipped with electric lighting and engine starting systems is in

the generator. With the engine of such a car idle, the source of ignition current used while starting the engine and for running at low speeds is the storage battery which has been previously charged from the generator.

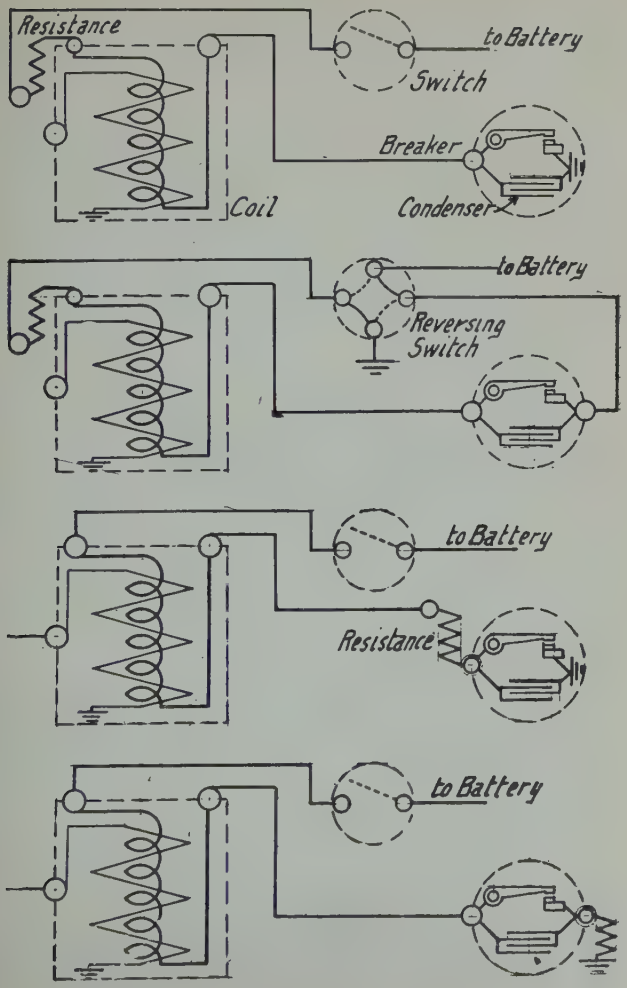
On many cars and trucks the electrical source consists of a magneto which is a form of dynamo-electric machine, especially adapted for the production of alternating current suitable for ignition, but not suited for the production of direct current to charge a battery.

DRY CELLS

For an emergency, or as an auxiliary source of ignition current, it is possible to use batteries of dry cells which may be switched into the ignition circuit. Dry cells are no longer used as the principal source of current for ignition, although at one time they were commonly found.

The cell consists of a cylinder of zinc inside of which is carried a carbon rod and with a filling of finely powdered carbon and black oxide of manganese between the zinc shell and the carbon. Saturating the filling between the carbon and zinc is the electrolyte or exciting liquid of the cell, which varies in composition according to the ideas of the manufacturer.

The zinc can is lined with a layer of some porous material, such as blotting paper, which holds a large proportion of the electrolyte and keeps the liquid in close contact with the zinc. The top of the cell is tightly closed with a sealing compound which prevents loss of the liquid by evaporation. The cell as thus far described is carried inside of a cardboard



Figures 8, 9, 10 and 11.—Ignition Circuits with Condensers in Breakers.

cover which is either cylindrical or square. This cover is the insulator for the zinc element and it must be preserved without opening or breakage except at the top, otherwise the cell will probably be short circuited on other cells or the metal of a box in which it may be carried. One terminal to which a wire may be secured is fastened to the upper edge of the zinc shell and another terminal to the carbon rod in the center of the cell. The terminal on the carbon is of positive polarity and from it the current flows, while the zinc terminal is negative and into this terminal flows the returning current form the outside circuits.

A single dry cell is capable of causing an electrical pressure of 1½ volts. This pressure is the same whether the cell be large or small in size. The rate of flow or the amperage that may be taken from a dry cell depends on its size, being greater in a large cell than in a small one. The size generally used is called a number 6, is 2½ inches in diameter and 6 inches high. The maximum current drawn from this size cell should not exceed one-half ampere if its maximum practical life is to be secured.

The life of the dry cell is determined by the rate of discharge and by the length of the periods between use. A cell will give a flow of fifteen or more amperes provided the resistance of the outside circuit is low enough to allow the pressure of 1½ volts to cause this flow. In this case, however, the life of the cell would only be a few minutes. With a low discharge rate, such as one-half ampere, the cell will last for fifty or sixty hours of intermittent use. A dry cell gives best service under conditions which allow it fairly long periods of rest between periods of current with-

drawal, these periods allowing recuperation and a renewal of its ability to do work.

While the cell is delivering current, hydrogen gas is generated by the internal action. This gas is an insulator and it reduces the current output of the cell. The formation of the gas is called polarization of the cell. The mixture of carbon and oxide of manganese is called a depolarizer and from it is liberated oxygen gas which combines with the hydrogen and forms water during the time the cell is at rest. The removal of the hydrogen gives the cell new life and it will again give its normal output.

The ignition systems in general use require a greater voltage for the primary circuit than may be secured from a single dry cell and in order to obtain this voltage a number of cells are connected with each other in series as shown in Figure 12. In a series connection the carbon or positive terminal of one cell is connected with the zinc or negative of the second, the positive of this second with the negative of the third and so on for the whole number of cells in the series. The voltage between the carbon positive terminal of one end cell and the zinc negative terminal of the cell at the other end of the series will now be approximately equal to the voltage of one cell, which is 1½, multiplied by the number of cells connected together. Thus, four cells will provide six volts; eight cells will provide twelve volts and so on for any number. In practice it is customary to add one more cell than called for by this rule, the added cell's pressure making up for the additional resistance of the parts and connections of the series.

While a series connection of dry cells increases the voltage it does not increase the flow or amperage that

may safely be taken from the battery. In order to increase the available amperage the cells are connected in multiple or shunt with each other. This multiple connection, also shown in Figure 12, is made by connecting together all of the negative terminals of several cells and then connecting all the positive terminals with another wire. The voltage of any number of single cells in multiple would still be only

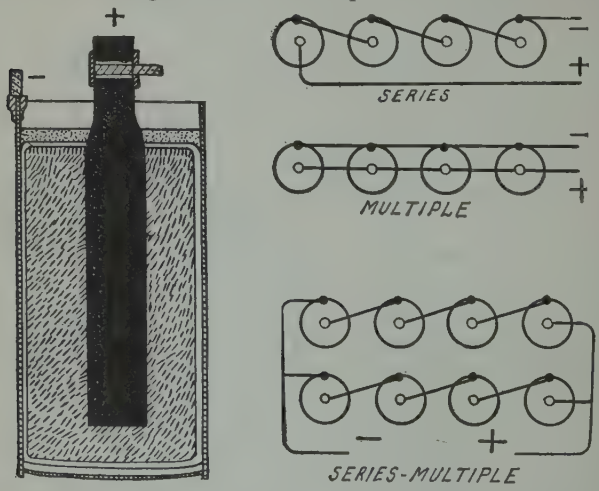


Figure 12.—The Dry Cell. Left: Section Through Cell. Right: Methods of Connecting Cells.

as great as from one cell, or 1½ volts, but it is allowable to draw an amperage equal to the allowable amperage from one cell multiplied by the number of cells in the group so connected.

When it is desired to increase the voltage and also to increase the amperage the dry cells are connected in series-multiple. In using this method of

connection a sufficient number of cells are connected in series to provide the required voltage and two or more of these series batteries of cells are made up. The end negative terminals of the several batteries are then connected with each other and the several end positives are likewise connected together as also shown in Figure 12. From the wires used for making this multiple connection may be secured a voltage equal to the pressure of one of the series sets and an amperage equal to the number of sets multiplied by the amperage of one cell. The life of a given number of cells connected in series-multiple is much greater than would be the life of a number of series sets used one at a time following each other. Thus the life of one series-multiple set of ten cells connected in two series batteries of five cells each will be more than twice the life that would be secured from one of the series sets of five cells when used alone.

IGNITION COMBINATIONS

Various names denoting certain combinations of magnetos and battery systems have come into use and have been generally accepted. These combinations are described in the following paragraphs.

An engine is said to be provided with single ignition when the sole source of current is a magneto or else a battery. An engine having a magneto only is fitted with a single ignition system or an engine having only a battery and dynamo is said to have single ignition.

Should an engine be fitted with a magneto and all of the other parts required for production and use of the spark in the cylinder, and also with a battery connected with an entirely separate and distinct set

of parts for ignition, this engine is said to have double ignition. When double ignition is installed it is possible to remove either the magneto system or the battery system in its entirety and to run the engine on the remaining system.

An engine may be equipped with a magneto which is alone capable of generating a high tension current ready to cause a spark, and in connection with this magneto may be fitted a battery having a separate induction coil used only with the battery current and not when the magneto is in action. Except for the coil all other parts of the ignition system, such as the device for interrupting the flow of primary current and the wiring leading to the cylinders, are used either with the magneto or battery as a source of current. Such a combination is called a transformer coil or a dual ignition system and by some makers has been given the name of duplex ignition.

Many makers who call the combination just described a duplex system also make a type given the name of dual, but in the dual they provide one device for interrupting the flow of current from the magneto and a separate device for use with the battery current.

Some magnetos are so constructed that they contain as a part of their armature winding an induction coil from which is secured high tension current for the spark; these machines being called true high tension magnetos. A true high tension magneto may be used either for a single ignition system or for a dual or duplex system, also as a part of a double system.

Other magnetos generate only a low tension or low voltage current and are used in connection with a separate induction coil mounted at another point on

REVIEW OF CHAPTER I

ELECTRIC IGNITION

Jump spark ignition is the only type used on automobile engines.

The **four strokes** of the four cycle engine, in the order in which they occur are: Inlet, compression, power and exhaust.

The **firing point** comes at or near top center between the compression and the power strokes.

Spark advance is required because of the delay that takes place between passing of the spark in the cylinder and complete ignition of the gas.

Variable spark systems allow changing of the time during the engine stroke at which the spark takes place.

Set spark systems always cause the spark to take place at the same point in the engine stroke.

The **induction coil** has two windings, a primary or low tension, and a secondary or high tension.

High voltage is caused in the secondary by mutual induction when there is a quick change of current (decrease) in the primary winding.

Sources of ignition current include generators, storage batteries, magnetos, and dry cells.

The **voltage of dry cells** in series is equal to the number of cells multiplied by 1½. The voltage of any number of dry cells in multiple is 1½.

A single ignition system has but one source of current, usually a magneto system. A **double ignition** system has two complete ignition equipments, each entirely independent of the other. **Dual or duplex systems** have two sources of current, but use some or all of the other parts in common for both sources.

CHAPTER II

PRODUCING THE SPARK

CONTACT BREAKERS

It has been explained in the preceding chapter that the greatest voltage is secured from an induction coil at the instant the primary circuit is broken. That part of the ignition mechanism which causes this break is called the contact breaker, circuit breaker or interrupter and is a part with which the ignition worker is apt to become well acquainted, both because of the importance of this device and because of the interesting methods that have been adopted in its construction.

The principal parts of the breaker include two contact pieces through which the primary circuit for the induction coil passes while these contacts are touching each other and which, when separated, prevent a further flow of this primary current. In connection with the contacts, or, as they are often called, the contact points or simply the points, there is a cam which causes their separation at the instant a spark is desired in one of the engine cylinders. All of the remaining parts of the breaker are for the purpose of allowing the contacts and the cam to operate properly.

Proper operation of the breaker requires that the contact be quickly broken when it is time for the

spark to occur, for a gradual separation of the points would not produce a hot ignition spark. It is also necessary that the contacts remain closed long enough to allow the primary current through the coil to thoroughly magnetize the core, thus producing a strong magnetic field which will act on the secondary

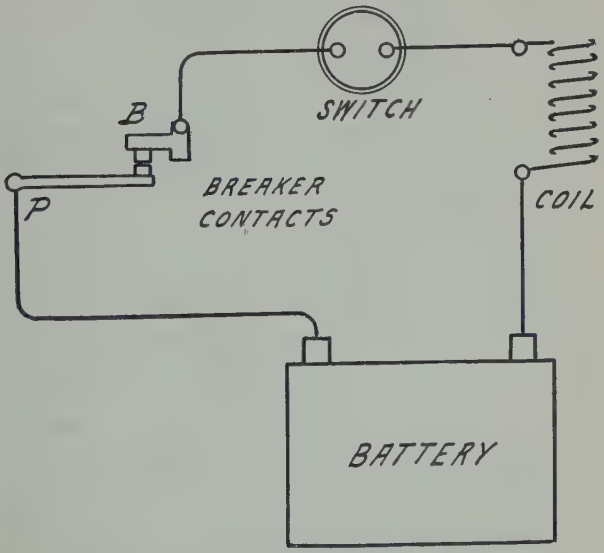


Figure 13.—Breaker Location in Ignition Circuit.

coil winding. This does not necessarily mean that the primary current should flow long enough to completely saturate the core in all cases, because a coil might be used which was built large enough to allow a partial magnetization of the core to do the work.

The location of the breaker in the primary circuit is shown in Figure 13. In this case the lower contact is the one that moves and it is carried by a lever one end of which is pivoted at P. The upper contact B is stationary. With the switch closed it is possible for the current to flow from the battery and through the primary winding of the ignition coil as soon as the contacts come together. The circuit is then complete through battery, coil and switch to the breaker contacts; then through these contacts as long as they remain together and from the pivoted end of the lever back to the battery. At the instant the contacts open, a spark will be caused to pass in the engine cylinder. Before another spark can be secured it is necessary that the contacts close and again magnetize the coil.

Insulated or Grounded Primary.—As shown in Figure 13 the entire circuit is carried through wires and parts which are insulated. This plan, when found, is called an insulated primary circuit. It has the same characteristics and advantages that are found in the two wire systems which were once the universal practice in electric lighting and engine starting systems, among these being the fact that both sides of the circuit from the battery would have to become stripped of their insulation before an accidental short circuit through other conductors would occur.

As generally found the primary circuit is completed through some of the metal parts of the engine and framework of the car to which the ignition system is attached. In this case the system is called a grounded primary type and the primary circuit is shown in Figure 14. One of the battery terminals is attached to the metalwork, or grounded, and one or the other of the contacts of the breaker is likewise

in metallic contact with the remainder of the metal parts so that the current is free to flow through this uninsulated portion of the circuit because of the fact that all metals form excellent conductors.

Breaker Contacts.—At the point of actual opening in the primary circuit it is necessary to guard against

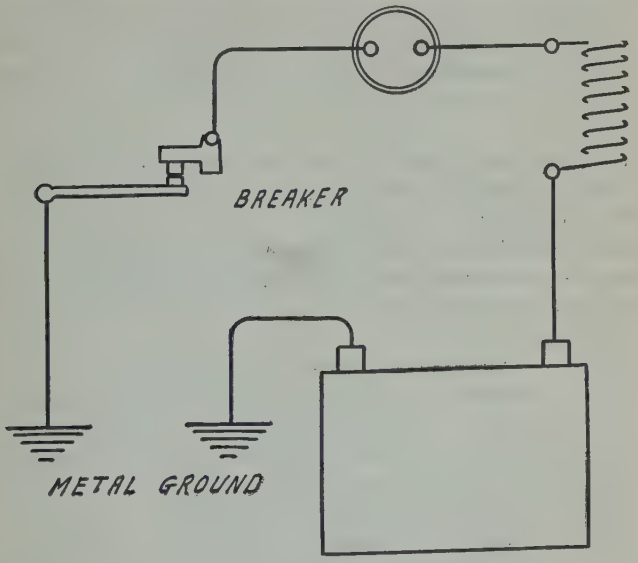


Figure 14.—Grounded Primary Circuit.

the effects of heat due to the small arc or spark that occurs at the instant of separation. This calls for a material that will successfully resist a high degree of temperature while at the same time conducting the current with but slight resistance.

A metal very commonly employed for making the contact points is platinum which will only melt at

very high temperatures and which is but slightly affected by the action of air. Because of the cost of platinum very little is used except where absolutely necessary and the contacts are therefore seldom more than $\frac{1}{8}$ inch thick and $\frac{3}{16}$ inch in diameter. Oftentimes they are made much smaller than these dimensions. The platinum is sometimes alloyed with iridium, another rare and costly metal, which gives the point greater hardness and resistance to the hammering action than could be secured with pure platinum.

A large number of the breakers now being made are equipped with contact points of tungsten, a metal which combines resistance to heat with very good wearing qualities. Alloys containing silver have also been used to some extent for making contact points but the metals tungsten and platinum are almost universally favored.

One of the contact points is stationary while the other is movable. The stationary contact is securely mounted on the body of the breaker and is the member provided with means for changing the distance between the points when separated, that is, the stationary contact is adjustable. The other contact is moved to open and close the circuit and is not adjustable. The stationary contact may in some cases be mounted on a spring to give certain flexibility as the points come together and in such a construction it is not, strictly speaking, stationary. Inasmuch as one of the contacts is acted upon to cause the breaker action it may always be spoken of as the movable contact, and the remaining one, however mounted, is called stationary.

Contact Point Adjustment.—It is necessary that

the contact points separate a certain distance from each other when the circuit is opened by the breaker, this distance usually being in the neighborhood of eight to fifteen thousandths of an inch. With use the surfaces of the contacts will wear or will become uneven and require filing. In either case the reduction of thickness of the contact metal will cause the opening to become greater than when the breaker was new and some means must be provided to again obtain the correct distance.

In Figure 15 are shown methods of adjustment which are in quite general use. In almost all cases the adjustable contact is carried on the end of a threaded screw and by turning this screw one way or the other the distance apart of the points when separated may be made more or less, whichever may be required.

At A, B and C are shown methods of securing a screw which carries the adjustable contact with one or more locking nuts. At A the screw passes through the supporting body of metal and carries a locking nut on the end opposite the contact while the screw itself is hexagonal at one end to allow turning with a small wrench. At B the screw passes into the supporting metal and is prevented from turning by a single locking nut. At C the screw carries a hexagonal head to which a wrench may be fitted and the adjustment is maintained by two lock nuts, one on either side of the support.

D, E and F show methods of clamping the screw which carries the contact. At D the supporting metal is slotted on one side and a clamping screw draws the sides of the slot together, thus binding the threads of the contact screw. The screw itself is turned by

inserting a small rod through holes in the enlarged portion near the contact. The method shown at E is somewhat similar to that at D with adjustment of the contact screw provided for by the knurled head. At F substantially the same result of clamping is

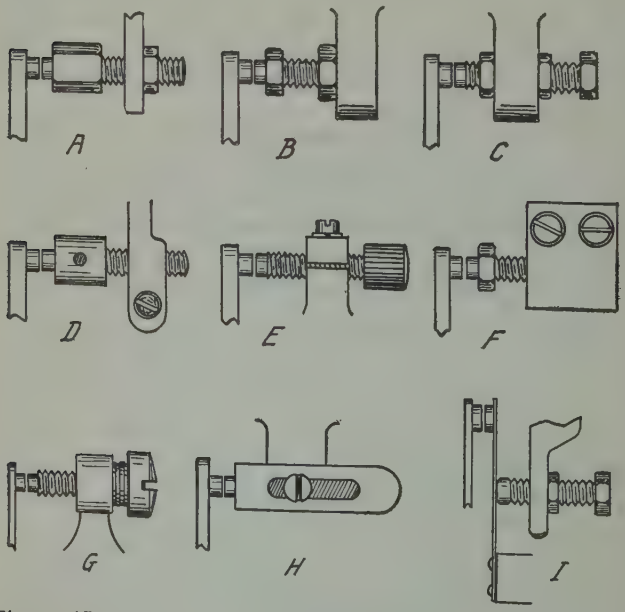


Figure 15.—Methods of Adjusting Breaker Contact Point Gap.

secured, but in this case by means of two locking screws rather than with one.

At G the contact screw is provided with a number of very thin washers underneath the head and between the head and the support. The adjustment is

made by taking the screw out of its support and adding or substracting one or more of the thin washers, after which the screw is turned back into place until secure. At H the adjustable contact point is carried on one end of a slotted rod and through the slot is a locking screw. The adjustment is made by loosening the locking screw and pushing the rod one way or the other on the screw, after which the adjustment is made secure by tightening the lock. This type of adjustment does not revolve or otherwise change the position of the contacts in relation to each other regardless of change in gap. With the method shown at I the contact point is carried at one end of a flat spring. An adjusting screw with lock nut is provided which bears against this spring and by turning the screw one way or the other the spring is bent to bring the points closer together or farther apart as may be desired.

BREAKER CAMS

The movable contact of the breaker is acted upon by some form of cam which is in turn operated by power from the engine. The shaft from which the cam is revolved is driven from the engine by positive means such as gearing or chains because it is necessary that the cam act to open the contacts at one certain time in the engine cycle in order to secure ignition at the end of the compression stroke.

In magneto construction, the breaker base, together with the contact carrying parts, may revolve as a unit; the cams then being mounted in the housing and remaining stationary. This is the reverse of the method generally used with battery systems. The

following matter in this chapter refers particularly to battery ignition.

In the four cycle engine each cylinder fires once for each two revolutions of the crank shaft. A single cylinder engine would therefore require one spark, which would call for one separation of the breaker contacts every second revolution of the crankshaft. A two cylinder engine would require twice as many sparks, or one for each revolution of the crank shaft. Four cylinders call for two sparks each crankshaft revolution, six cylinders for three sparks, eight cylinders for four sparks and twelve cylinders for six sparks each revolution. In other words, an engine will require a number of sparks during each crankshaft revolution which is equal to the number of cylinders divided by two and each spark calls for one separation of the breaker contacts.

The breaker shaft of battery ignition systems operates in practically all cases at the same speed in relation to the engine crank shaft as does the shaft which opens and closes the valves for the various cylinders, this being one-half as fast as the crank shaft. The cam which opens the breaker contacts will therefore require as many lobes or points which cause the contacts to separate as there are cylinders of the engine. This last statement holds true in all cases where the breaker is provided with but one set of contacts in operation at one time. Very high speed engines of six, eight and twelve cylinders are sometimes provided with two sets of contacts opening alternately which of course cuts the number of cam lobes in half.

In Figure 16 are shown forms of breaker cams, all of which are found in the installations on various cars

and of various makes of ignition equipment. At A are shown very simple forms in shapes suitable for firing four cylinders (square), six cylinders (hexagonal) or eight cylinders (octagonal). With rotation of such a cam the contacts will be separated each

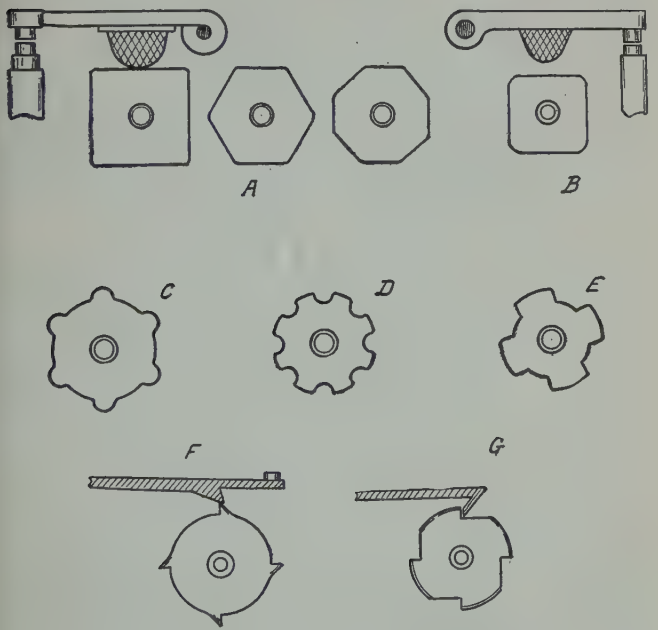


Figure 16.—Construction of Breaker Cams.

time one of the corners strikes the projection on the arm or lever which carries the movable contact point. In order to secure the desired opening between the contacts, but still without causing them to remain together as long as would be the case in the forms

shown at A, the corners may be rounded as shown at B. This form keeps the contacts apart while the projection on the lever rides over the rounded portion and allows them to close only while the flats of the cam pass under the lever. The longer flats shown at A allow a longer time for closing of the contacts which of course calls for a greater expenditure of current due to the longer time of contact.

The three forms of cams shown at C, D and E are all modifications of a circle. At C the lobes are formed on the outside of the circle while at D, an eight cylinder type, the lobes are formed by cutting small arcs of circles into the circumference of the cam. At E is shown another four cylinder type.

At F is shown a cam which closes the contacts only during the very short length of time during which the contact carrying lever rides over the outer end of one of the small points formed around the cam body. The shape of this cam, in which one side of the point rises gradually, while the other drops very abruptly, causes a quick break as the contact lever drops off the top of the point.

The cam used with Atwater-Kent systems of one type is shown at G. This form consists of a series of notches, one for each cylinder, cut into the circumference of a circle. A hooked arm catches in the notch as the cam turns and the arm is drawn in the same direction that the cam rotates. With continued turning the hook of the arm slips out of the notch and the quick return opens the contacts. This type is fully described in Chapter V.

In the early types of Westinghouse apparatus no separate cam was provided but the contacts were caused to separate when one of the centrifugal gov-

ernor weights struck against a spring arm which released the lever to which the movable contact was attached. This form of apparatus is not used in present models.

In most cases the breaker cam is solidly fastened to its shaft and in order to change its relation to the engine parts the relative position of the driving gears or chains must be altered. One exception to this practice occurs in those equipments wherein the cam is secured to its shaft by means of a screw with a tapered head which threads into the shaft and holds the cam in position by the tightly drawn taper fitting.

BREAKER ARMS AND LEVERS

The movable contact of the breaker is carried by a hinged or pivoted arm or lever which allows the necessary opening to take place between the contacts while in operation. Inasmuch as this arm or lever, with its attached contact, must move once for each spark produced it must be capable of performing these movements with exceeding rapidity. The lever is held in one position, either with the contacts open or closed, by a spring and is then operated by one of the forms of cams already described. Lightness is generally desirable in a breaker arm so that the mechanical lag may be reduced as much as possible.

One end of the breaker arm is generally supported by a hinge of some kind. In most cases this hinge is formed by a pivot carried by the breaker body and over which fits a hole in one end of the arm. In many constructions this hole carries a bushing or lining of fibre so that the two metal surfaces are kept apart and the danger of binding is reduced. A hinge may also

be formed by attaching a thin flat spring to one end of the arm and supporting the other end of this spring on part of the breaker base, the spring allowing sufficient movement of the arm for opening and closing of the contacts.

Breaker arms may be straight or nearly straight from end to end. They may also be curved or L shaped. The form of arm has but little to do with its action but is adopted to accommodate the shape of the whole breaker mechanism, whether long or circular.

The contact point may be carried on the end of the lever farthest from the hinge, in which case the

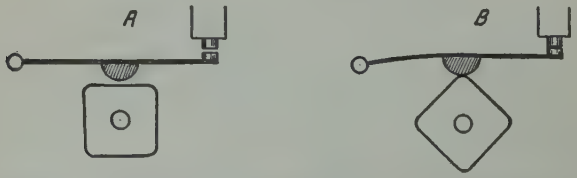


Figure 17.—Action of Breaker Cam on One Piece Arm.

cam acts on the lever at or near its center; or the contact may be near the center of the lever and the cam may then act on the lever's end. The lever is fitted with some form of bumper against which the cam strikes, this bumper being made from fibre or from the metal itself. The fibre bumper may be in the form of a block of suitable shape or may be circular. A circular bumper is sometimes capable of being turned around its axis so that new surfaces are presented to the cam as old ones become worn.

A number of breaker constructions make use of contact levers formed of two pieces of spring steel,

one of which carries the contact point while the other is directly acted upon by the cam. This form of lever is found in those systems which provide that the cam close a pair of contacts which are normally open. The

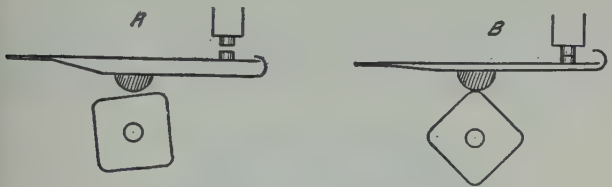


Figure 18.—Action of Two Piece Breaker Arm.

reason for employing a double spring arm may be understood by reference to Figures 17 and 18. In position A of Figure 17 the contacts are open and the spring arm carrying the movable contact is straight. With the contacts closed because of cam action, as shown at B, the spring lever has been bent. Such action could not continue as the bending would soon destroy the lever's usefulness.

In Figure 18 is shown a form of double spring arm which obviates the difficulty that would be found with but a single spring. In the open position at A the

Figure 19.—Two Piece Breaker Arms. Left: Westinghouse. Right: Delco.

hooked end of the spring which carries the bumper is holding the contacts apart. At B the cam is shown in position to close the contacts, the hooked member having moved the contact carrying spring until the

contacts are together, then continued its movement until the point of the cam has passed, but without further movement of the contacts themselves.

Double levers which operate in much the same way as the form just described are shown in Figure 19, that at A having been used with some of the earlier Westinghouse installations and that at B being a form used by Delco. Types of intermediate arms or strik-

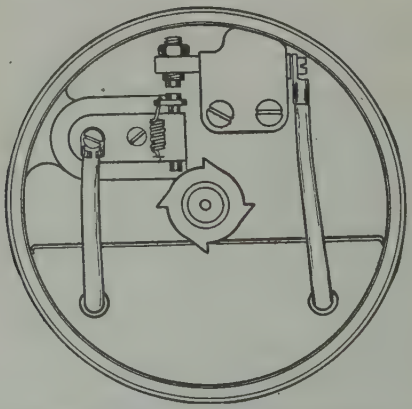


Figure 20.—Breaker Using Intermediate Striker (Philbrin).

ers which act between the cam or cam operated lever and the arm carrying the movable contact are shown in Figures 20 and 61. The form having three levers in Figure 61 is an Atwater Kent characteristic and the form in Figure 20, which utilizes a small plunger for carrying the contact, being found on Philbrin systems.

It has been found that the speed of some multi-cylinder engines may call for a number of sparks greater than can readily be furnished by a single

breaker because of the fact that the contacts cannot remain together for a long enough time to insure magnetization of the induction coil. To obviate this difficulty, breakers have been made with two levers and two sets of contact points. A form of Delco equipment having two levers operating from different points around the same three lobed cam and carried in a plane with each other is shown in Figure 21. A

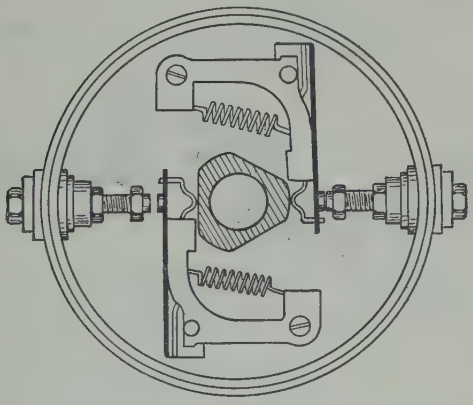


Figure 21.—Double Arm, Single Cam Breaker for High Speed Engines (Delco).

Remy design for high speed engines provides two contact arms both operated by one cam and carried one above the other. In this connection it may be noted that a twelve cylinder engine running at 1800 revolutions per minute calls for one hundred and forty sparks during every second of operation, or 8,400 during each minute.

In Figure 22 is shown the contact point arrangement used with older types of Westinghouse equip-

ment. This construction hangs two movable contacts from a single bar, this bar being then operated by the lever against which the cam acts. The two sets of contact points are in a series with each other, current entering the breaker through one set, passing through the contacts and the supporting bar, then leaving the breaker through the remaining set of contacts.

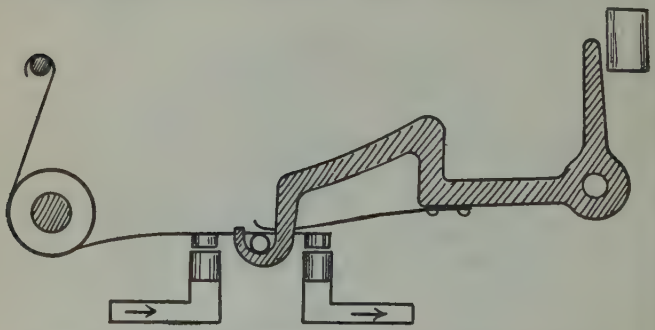


Figure 22.—Double Contact Breaker (Westinghouse).

THE CONDENSER

If a battery, coil and breaker be connected in a circuit as shown in Figure 23 it will be found that a powerful and hot spark will be produced at the breaker contacts as they separate. This spark has sufficient heat to quickly destroy the contact points and is caused by an action in the coil which is called "self induction."

It has been explained that the change of magnetism in the core of the coil which takes place upon breaking the primary current causes a flow of current in the secondary winding of the coil and this same change

of magnetism produces a flow of current in the primary winding as well. This induced flow caused by breaking the current at the points is of much greater voltage than the primary current itself and tends to continue to flow between the contacts as they open, thus causing an arc or hot spark.

A device called a condenser is incorporated in the ignition apparatus for the purpose of collecting this induced current, preventing its causing a destructive arc at the contacts and also allowing the power of the induced current to be returned to the coil in such a

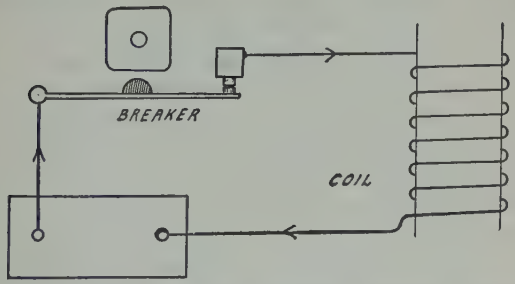


Figure 23.—Primary Ignition Circuit Without Condenser.

way that the change of magnetism affecting the secondary winding is greatly increased and the resulting current in the secondary circuit is raised in voltage to produce a spark much hotter than would otherwise be secured.

The condenser consists, in the form usually employed, of a number of strips of tin foil separated by insulators such as oiled or parafined paper or sheets. Mica also is used in some cases as the insulator. Alternate strips of the tin foil are attached to each other so that one half the total number of strips con-

nects with one terminal of the condenser while the remaining half connects with the other terminal. This arrangement provides a large surface of an electrical conductor (tin foil) separated by very thin layers of insulating material, which is, in this case, called the dielectric. A condenser has the ability to hold a certain amount of electrical energy which is stored on the conductor sheets when the condenser terminals are subjected to a difference of voltage, as would be the case when connected in the primary circuit across the breaker contacts. The position of a condenser, connected between the breaker contacts, is shown in Figure 24.

As the breaker contacts open, the magnetism dies out of the core of the coil and this change in magnetism induces a current in both primary and secondary windings. Whereas the voltage from the battery and dynamo may be between six and eight, the induced voltage in the primary winding of the coil may rise to one hundred or one hundred and twenty-five volts. In place of expending itself in forming an arc between the breaker contacts, this high voltage charges the condenser and the condenser then immediately discharges itself back through the coil, but in a direction the reverse of that taken by the battery current. This powerful reverse discharge from the condenser quickly demagnetizes the core of the coil and remagnetizes it in the reverse direction with the result that the total change of magnetism, from that first caused by the battery current to that of reverse polarity caused by the condenser's discharge, is very great and a very high voltage is produced in the secondary winding with a resulting hot spark at the plugs in the cylinders.

Should the condenser fail because of becoming disconnected the result will be severe sparking at the breaker contacts and a weak spark at the plugs. Breaking down of the dielectric or insulation between the leaves of the condenser will short circuit the contacts and weaken or prevent the spark at the plugs.

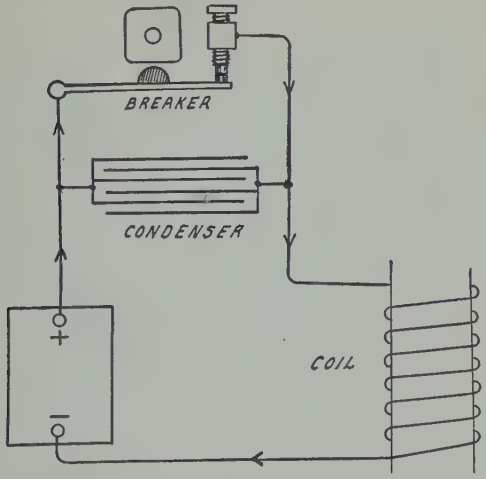


Figure 24.—Location of Condenser in Primary Circuit.

The condenser may be located in the breaker housing very close to the contacts themselves, or in the coil housing or as a separate unit in its own housing at some point between the coil and breaker. It is thought best to carry the condenser as close as possible to either coil or contacts, so that wiring between these parts is greatly reduced or in some cases practically eliminated. The best practice is undoubtedly to have the coil, the breaker and the condenser as close to each

other as possible so that the primary wiring, except that to the battery and switch, is reduced to a minimum. In this way the flow of current between coil and condenser finds but very little resistance and the same is true of the flow past the condenser to the breaker contacts.

THE DISTRIBUTOR

The distributor receives the flow of secondary or high tension current from the fine wire winding of the spark coil and directs this flow of current into the wire leading to the spark plug in the cylinder which is then ready to fire, that is, to the cylinder whose piston is at the upper end of its compression stroke and ready to descend on the power stroke.

The distributor consists of an insulating cap or head in which are secured the terminals to which spark plug wires attach and in most cases in which the terminal carrying the wire from the spark coil is also mounted. Inside of the cap is a revolving member called the rotor which receives the high tension current from the coil, and, by moving from point to point around the cap, carries this current to segments or pins which are in electrical connection with the several spark plug wires.

The electrical connections for the distributor are shown in Figure 25. From the secondary winding of the coil a flow of current takes place each time the breaker contacts separate and this flow passes through the line C to the rotor of the distributor. As each flow of current is received, the rotor is in position to carry the current to one of the terminals and from this terminal the current is carried to a spark plug.

Jumping the gap in the plug, the current produces the spark which ignites the mixture and then continues through the metal shell of the plug to the ground or metal of the engine and car. The other end of the secondary winding of the coil is also grounded to the metal work so that the high tension current passes back to the coil winding and completes the high

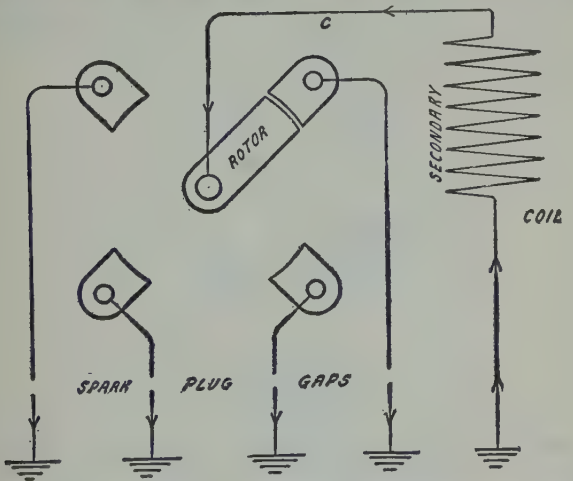


Figure 25.—Location of Distributor in High Tension Circuit.

tension circuit. By the time the breaker contacts again open, the distributor rotor is in position to send the current to the plug in the cylinder then ready to fire and the action continues in this way.

Because of the necessity of revolving the rotor to keep time with the action of the breaker, the distributor of battery systems is generally carried directly above the breaker housing and the rotor is mounted

on the upper end of the shaft which carries the breaker cam. The rotor is so placed in relation to the lobes on the cam that each time the contacts separate, the rotor is in position to send the high tension current to one of the plugs.

In some forms of battery ignition apparatus and generally with magnetos the distributor is mounted above the breaker but with both breaker and distributor rotating in the same plane as shown in Figure 26. In this type of equipment the breaker cam has

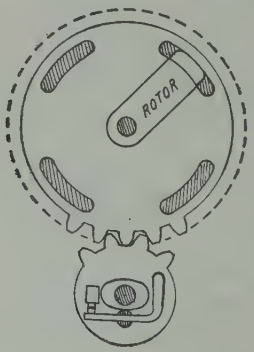


Figure 26.—Breaker and Distributor of Magneto Type.

only half the number of lobes as there are cylinders to be fired and the distributor rotates at one half the breaker speed. The driving connection between the two parts is secured by a gear carrying the distributor rotor meshing within a pinion smaller than this gear and mounted on the breaker shaft.

Two distinct types of distributor construction are in use. One type, called the wipe contact, provides carbon or metal brushes in the distributor rotor or the cap, or in both rotor and cap, which complete the

connection for the high tension current. The other type, called a jump spark distributor, leaves a minute air gap between the current carrying member of the rotor and the connection for the spark plug cable terminal, the secondary current jumping across this air gap for each discharge of high tension current.

Jump Spark Distributor.—The jump spark distributor includes a rotor having a metallic current carrying member mounted on the body of the rotor and with its outer end traveling very close to a series

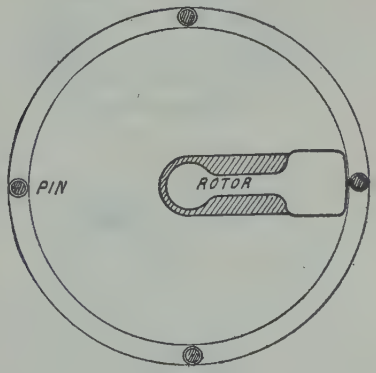


Figure 27.—Rotor and Segment Pins of Jump Spark Distributor.

of pins set into the cap or head of the distributor as shown in Figures 27 and 60. One pin is provided for each spark plug cable and the outer end of the rotor metal is made wide enough so that, regardless of the degree of advance or retard, within practical limits, the rotor is always opposite one of the pins during the discharge of high tension current to the plug. The center of the rotor, at which point the current is received from the coil winding, may receive its cur-

rent through another pin and across a gap similar to those leading to the spark plug lines, through a spring contact bearing against a metal segment or pin or through a carbon or metal brush carried in the cap or by the rotor. The positive spring or brush contact for the coil terminal is generally favored in preference to the jump spark type at this point.

The gap between the outer end of the rotor and

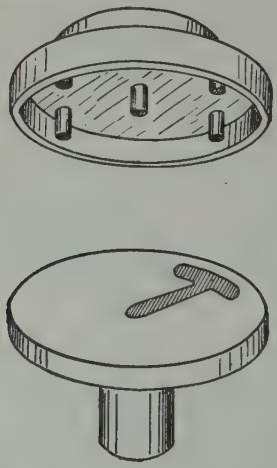


Figure 28.—Rotor and Brushes of Wipe Contact Distributor.

the spark plug pins is generally made from five to eight thousandths of an inch, or about one fifth the gap used between the points of the spark plug. This gap should be sufficient to prevent either rubbing contact or any excess space at this point. One purpose of using the jump spark type rather than the wipe contact form is to do away with the rubbing action necessary in the wipe contact but it is not

intended to cause any more resistance than is absolutely necessary.

Wipe Contact Distributor.—The wipe contact distributor, shown in Figure 28, introduces no additional air gaps into the secondary circuit but does make use of two sliding contacts, one as the current enters the distributor from the coil and the other as the current leaves to the spark plug lines. While metal brushes, solid and of button shape, have been used in completing these sliding or wipe contacts, the general practice is to use cylindrical or rectangular pieces of carbon held in contact with metallic pieces by means of small coiled springs. Brushes made from fine mesh copper wire screen wound into cylindrical form have also been used from time to time.

In the form of wipe contact distributor shown, all of the brushes are carried in the cap or head. There is then one central brush connecting with the lead from the coil and resting on the center part of the rotor metal. Around the edge of the cap are brushes equal in number to the number of cylinders of the engine. These brushes bear on the outer end of the rotor as it revolves. The rotor itself consists of an insulating plate, perfectly flat in the portion traveling under the spark plug brushes and with a metal piece set flush with the insulating plate. This metal piece makes contact with the coil brush at the center of the rotor and passes successively under each of the spark plug brushes during rotation.

A generally used form of wipe contact distributor, as shown in Figure 29, carries two brushes in the rotor, one of these brushes being always in contact with a segment in the cap which connects with the coil terminal while the other brush is at the revolving

end of the rotor body and makes contact successively with segments set flush with the insulating material of the cap and which connect with the wires leading to the spark plugs for the several cylinders.

In other constructions the rotor carries one brush at its revolving end, this brush making successive contact with segments for the spark plug lines, while the coil terminal brush is mounted in the cap and bears on a metal piece in the center of the rotor with elec-

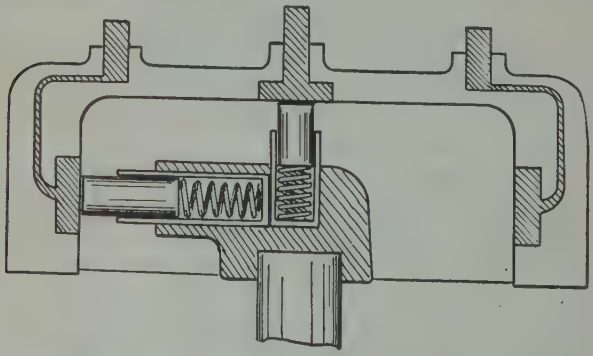


Figure 29.—Wipe Contact Distributor Construction.

trical connection between this center piece and the holder for the revolving brush. Some models of Westinghouse equipment carry two brushes, one above the other, in the revolving end of the rotor. In this case the high tension from the coil is lead to a ring around which the lower brush travels while the upper brush moves around a track in the cap which includes segments for the spark plug lines.

REVIEW OF CHAPTER II

PRODUCING THE SPARK

The breaker includes the two contact points, the arm and support carrying them, the spring, the cam, the housing, and their fastenings.

The **spark takes place** at the instant the contacts separate.

The **primary circuit** may have both sides completely insulated, or one side may be grounded.

Contact points are generally made of tungsten, but sometimes of platinum.

The **stationary contact is adjustable** to change the breaker contact gap.

The **number of sparks** for each crankshaft revolution is equal to the number of cylinders divided by two for four-cycle engines.

The **breaker shaft** usually rotates at half crankshaft speed, or at the same speed as the cam shaft.

With breakers whose **contacts are held closed** by the spring, the spark occurs when the cam strikes the arm; with breakers whose **contacts are held apart** by the spring, the spark takes place when the cam leaves the arm or bumper.

Eight and twelve-cylinder engines often use breakers having two sets of contacts and two arms operated by one cam.

The **condenser consists** of two sheets or two sets of sheets of lead or aluminum foil separated by layers of thin paper or mica. Direct current will not pass through a condenser.

The **condenser's function** is to absorb the current of self-induction and prevent an arc at the contacts when they separate; also to discharge back through the primary winding in a reverse direction and thus assist in quickly demagnetizing the core.

Condensers are located in the coil, in the breaker housing, or just outside either the coil or breaker.

The **distributor** receives the high tension impulses from the coil secondary winding and sends them through the revolving rotor to the cylinder ready to fire.

Jump spark distributors have gaps of a few thousandths of an inch between the rotor and the pins attached to the spark plug wires.

Wipe contact distributors use brushes against segments in the rotor or distributor cap, and have no gap in the circuit.

CHAPTER III

THE IGNITION CIRCUIT

CLOSED AND OPEN CIRCUIT SYSTEMS

An ignition breaker may be so designed that the contact points are normally held closed by a spring and are opened by the action of the cam, or it may be so built that the contacts are held open by the spring and are closed by the cam. The first method, with the contacts normally closed, is called a closed circuit system, while the second, with the contacts held apart until pressed together by cam action, is called the open circuit system. Delco, Atwater Kent and Westinghouse systems have been built in both types. Remy, Connecticut, Bosch and Splitdorf equipment has favored the closed circuit plan, while Pittsfield, Philbrin and Rhoades form examples of open circuit systems.

The two principles of construction, one closed circuit and the other open circuit are shown in Figure 30. At A is shown the construction of a closed circuit type in which the contacts P are held closed by the spring S until the cam D strikes the bumper on the arm E which carries one of the contact points. At this instant the contacts separate and the spark is produced. The contacts remain apart until the lobe of the cam passes from under the bumper. The primary current flows through the coil during the time

between the instant at which the cam allows the spring to close the contacts and the instant at which they are once more separated.

At B is shown the principle used with open circuit systems. The contacts P are held apart by the spring arm S until the cam D strikes the bumper. As the arm S is moved, arm E travels toward the stationary contact, until at some point which is determined by the initial gap between the contacts, they come together. At this instant the primary current starts to flow through the coil winding and continues to do so during further rotation of the cam. This continued

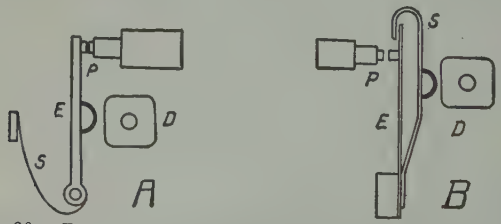


Figure 30.—Breaker Construction. A: Closed Circuit Type. B: Open Circuit Type.

movement of the cam carries arm S still closer to the stationary contact, but with the points once closed arm E no longer moves because the hooked end of S releases this contact carrying member to avoid undue pressure on the points themselves. As the lobe of the cam passes from under the bumper the spring arm S catches arm E by means of the hooked end and pulls the contacts apart. As they separate, the current stops flowing through the coil and the spark takes place. It will be noted that in the closed circuit type shown at A the spark takes place when the forward side of the cam lobe strikes the bumper, while in the open

circuit type shown at B the spark passes when the rear side of the cam lobe leaves the bumper.

In either of the types just explained it will be seen that with the cam lobe in the position as shown at A, or with the lobe directly under the bumper in the mechanism shown at B, primary current will flow through the circuit whenever the ignition switch is closed and with the engine idle so that the cam remains in the position mentioned in either case. It will also be noted that the time during which the contacts remain together will, of course, be longer with the engine running slowly than with it running fast. With the engine running slowly the cam is revolving slowly and it takes a certain definite interval for the lobe of the cam to act either in opening or closing the contacts. This same interval, determined by the engine speed, determines the absolute length of time during which the contacts remain closed and during which the core of the coil is being magnetized by the primary current. With increased speed of the engine the cam is traveling faster and the time interval, during which the contacts remain closed and allow current to flow through the coil, is correspondingly reduced.

With a cam built for a four cylinder engine and so designed that the time the contacts are open is just equal to the time between openings, and during which they are closed, the primary current would flow through the coil during thirty thousandths of a second at an engine speed of five hundred revolutions a minute. At an engine speed twice as fast, or one thousand revolutions a minute the coil would receive current during fifteen thousandths of a second and at fifteen hundred revolutions a minute for ten thou-

sandths of a second; the time in fractions of a second during which the core of the coil must be magnetized becoming less in direct ratio to the increase of engine speed. As a result of this condition in operation the coil windings must be so proportioned that the minimum possible time during which the contacts are closed, that is, at the highest attainable engine speeds, will be sufficient to build up the magnetism in the core of the coil to a point such that breaking of the

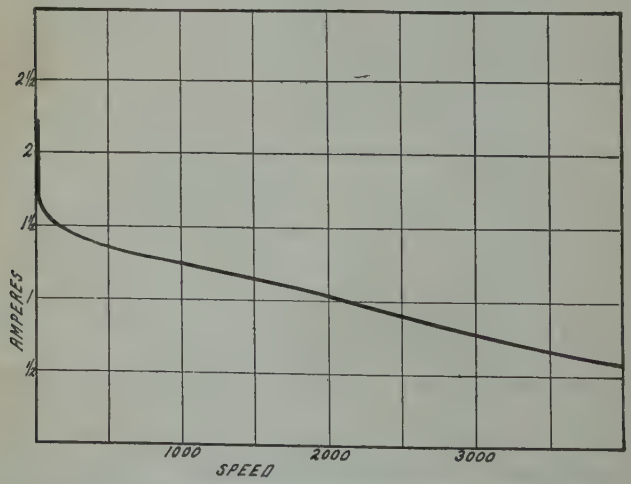


Figure 31.—Current Consumption of Closed Circuit System (Atwater Kent).

primary circuit will cause a reaction sufficiently powerful to produce a spark having heat enough to ignite the mixture.

It is also true that a strong spark is desirable when starting an engine from rest because of the lower compression and also because of the fact that the gases

are cold and tend to condense rapidly on the cylinder walls of the engine. The breaker types just described deliver their hottest sparks when the engine is being cranked because it is at this time that the coil is energized during the longest absolute time, while after the engine starts and with continued increase in crank- and cam-shaft speed the strength of the spark becomes progressively weaker.

The current consumption of the Atwater Kent closed circuit system is shown in Figure 31 for engine speeds from zero up to four thousand a minute. With the engine idle (zero revolutions) the current consumption is very high because there is a free flow from the battery through the primary circuit, hindered only by the normal resistance of the circuit. After the engine starts, the current consumption falls lower and lower with increase of engine speed because of the lessening time interval during which the breaker contacts are closed. With this decrease of current consumption there is a corresponding decrease in the heat or power of the spark delivered through the plugs.

The design of breaker shown in Figure 32 is of the true open circuit type in which the contacts are always open with the engine idle regardless of the cam position and in which the time duration of the contact between the points is constant for any and all engine speeds. The particular design shown is one of the first Atwater Kent constructions and well illustrates the principle involved.

The cam D is in this case formed with a series of notches around its circumference. As the cam revolves, it draws the latched arm T ahead with it as the latch catches in one of the cam notches. After the

latch has been drawn a certain distance ahead, the notch of the cam rides away from the hooked end and the latch, being thus released, is quickly drawn back by the tension of the small coiled spring S. In its backward travel the latch strikes a small extension on the compound breaker arm E just as the end of the latch passes over the high part of the cam which is between two notches. The contacts P are momen-

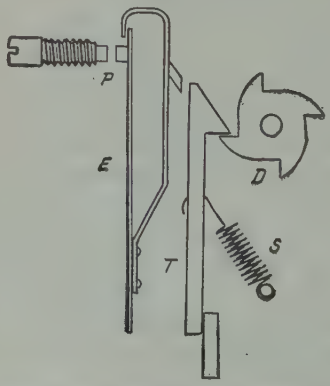


Figure 32.—Breaker of True Open Circuit Type (Atwater Kent).

tarily thrown together at this time and the primary circuit is completed. The arm E is immediately released and the contacts again open. In this case the length of time during which the contacts are closed in no wise depends on the speed of rotation of the cam or of the engine, but is governed entirely by the speed with which the latch is returned after its release by the coiled spring and this speed is the same regardless of all other conditions.

With such a type of true open circuit breaker the

coil windings are so proportioned that the necessary magnetization is accomplished during the time that the contacts are together and with this proportion right for one speed of the engine it is, of course, right for all other speeds and the value of the secondary spark is always the same, in starting and at all running speeds.

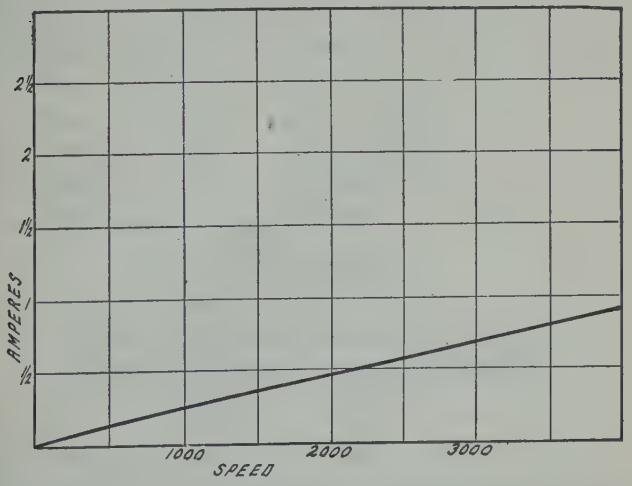


Figure 33.—Current Consumption of True Open Circuit System (Atwater Kent).

A true open circuit system uses more and more current as the engine speed increases due to the greater number of times that the circuit is closed, all of these times being of the same duration in fractions of a second. The current consumption of one of the new Atwater Kent open circuit systems is shown for various engine speeds in Figure 33. It will be noted

that the current consumption is very much less at low ranges of speed than with the closed circuit type and in no case reaches as great consumption as the closed circuit type at any engine speeds in ordinary use.

Another example of the true open circuit type of breaker is found in the Rhoades system, the construction of which is shown in Figure 34. The cam in the Rhoades breaker carries a number of projecting points and these revolve past an extension on the spring arm T, pressing this arm back. As soon as the point of

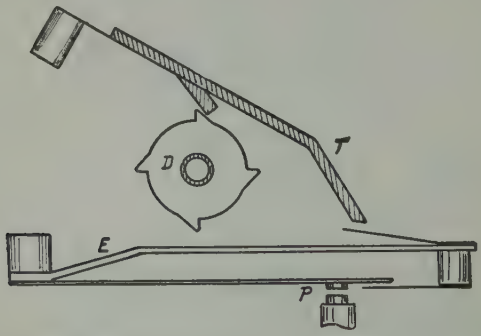


Figure 34.—Breaker of True Open Circuit Type (Rhoades).

the cam passes from under the extension on the spring arm the arm itself flies back and its free end strikes the outer end of the compound contact-carrying arm E. The force of the blow thus delivered causes the contacts P to be momentarily thrown together and the primary circuit is completed. At all times except when the arm E is struck by the spring actuated blow from arm T, the contacts are held apart and the circuit is open regardless of the position of the switch.

RESISTANCE UNIT

In the foregoing explanation of open and closed circuit systems it was shown that it is possible in the closed circuit and in the usual open circuit construction for the primary current to flow through the circuit with the switch closed and the engine idle. Such a flow of current would discharge the battery rapidly, would cause damaging burning of the metal composing the breaker contact points and would so heat the primary winding of the spark coil that this unit would eventually be rendered useless.

It was also explained that the current consumption with these types of breakers is greater at low engine speeds than at higher speeds and that the consumption at high speeds is sufficient to cause the coil to give a proper ignition spark.

For all of these reasons it is desirable that the flow of primary current be restricted at low engine speeds and that it be stopped or nearly stopped should the ignition switch remain closed with the engine idle. This object is accomplished by inserting in the primary circuit, usually near the coil or the breaker, a small length of wire arranged in a coil, this wire having the property of becoming heated with any great flow of current and when heated having the further property of greatly increasing its electical resistance. so that the flow of current through it is reduced to a low value.

The resistance unit is made from iron wire because this metal has the electrical characteristics mentioned, that is, increase of resistance after a certain critical degree of heat has been passed. The necessary length of wire is formed into a small coil and usually placed

around a heat proof spool which is then carried in a mounting open to air circulation. The heat may be radiated and the wire still protected against water and dirt falling directly into the coil. A sufficient length of wire is used to make the resistance of the unit considerably in excess of the resistance of the primary winding of the coil. This device is commonly found with battery ignition systems.

With a coil designed for battery ignition and to be used with such a resistance unit in circuit, the primary current at low speeds would be several times its normal value were the resistance unit taken out of the circuit. The primary current in such a circuit is limited by the combined resistance of the coil winding and the resistance unit, together with the impedence of the coil which is the choking effect opposing any pulsating current magnetizing an iron core. This impedence increases as the speed of the pulsations, due to the opening and closing of the breaker contacts, increases. At low speeds, due to the greater flow of primary current causing heating of the wire, there will be a consequent increase in its electrical resistance.

Should the resistance unit become short circuited damaging results to the breaker contacts, battery and coil will take place; while with the resistance unit broken or out of the circuit for any reason, there can be no flow of primary current and no spark will be generated.

SAFETY SPARK GAP

In order to pass across the gap in the spark plugs and thereby produce a spark in the mixture, the high tension or secondary current has a pressure of many

thousand volts. Should a spark plug wire break or should any other interruption take place in the normal path of the high tension current from the coil to the distributor, thence to the plugs and through the ground back to the coil, this great voltage tends to force the escape of the current through the easiest available path which may be through the insulation of the coil windings themselves or through the insulation of some of the other units in the circuit.

The voltage required to send the high tension current across the gap in the plugs and through the compressed mixture of fuel gas and air is about the same as that voltage which will send the current across a gap of one quarter of an inch in the outside air. The insulation of the coil windings and other high tension current carrying parts is strong enough to resist a current which would jump a gap of about one half inch in the air. The insulation resistance, being thus greater than the resistance across the spark plug gap, holds the secondary current to its proper path and forces it across the plug gap as the easiest place to escape to the metal or ground connection of the car.

Under most conditions of operation the proportioning of the battery voltage and the windings of the coil is sufficient to generate a secondary voltage high enough to send the current right through the insulation of the coil windings or spark plug cables were it not easier for this current to pass through the plug. It will be seen that a break in the line to the plugs will very likely result in serious damage unless some other path be provided through which the high voltage current may escape. This safety path is provided in the form called a safety spark gap.

A safety spark gap consists of two metal points

separated in most cases by a space of about three eighths of an inch, as shown on the coil in Figure 35. One of these points is in electrical connection with the secondary circuit after it leaves the coil winding, while the other point is in connection with the metal or ground. Inasmuch as the gap in the spark plug has a resistance equal to about one quarter inch of open air, while the opening of the safety spark gap is three eighths of an inch, the high tension current will take the path of lower resistance through the plug

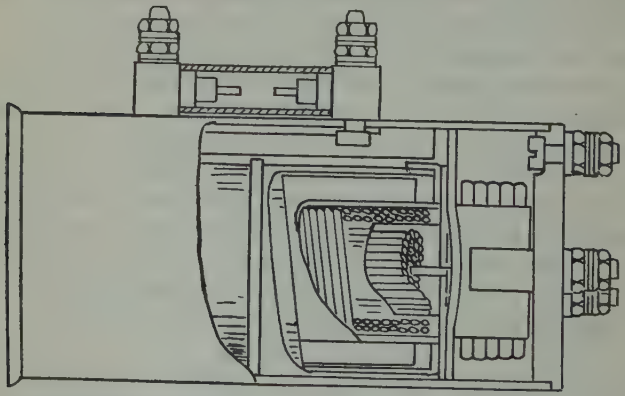


Figure 35.—Construction of Ignition Coil (Connecticut).

and will produce an ignition spark rather than flowing away at the safety gap. Should, however, the gap at the plug become so great as to introduce extraordinary resistance or should there be a break in the circuit so that the current could not reach the plug, then the secondary current will find the next easiest path to ground through the safety spark gap whose resistance, equal to three eighths of an inch of air, is still

less than the resistance of the insulation of the coil and ignition parts.

The safety spark gap may be carried on the body of the coil so that one of its points is connected directly with the outlet of the secondary winding, or it may be mounted or built into the distributor mechanism in which case it protects all of the secondary circuit except that part between coil and distributor. The location of the safety gaps is mentioned in Chapters V and VII on ignition equipment. Passage of a spark at this gap always indicates that there is excessive resistance, such as an incorrect spark plug gap, or a break somewhere in the high tension circuit and this break or resistance should be at once located and corrected.

IGNITION COILS

The mechanical construction of a coil is shown by Figure 35. The core is composed of a bundle of iron wire surrounded by an insulating covering. On the outside of this covering is placed the primary winding which consists of a few turns of comparatively heavy gauge wire. A second insulating covering is then applied and the fine wire secondary winding is placed over it. In the construction shown, the condenser is carried within the coil case and the safety spark gap is carried on the outside of the case. The parts have nothing to do with the coil proper but are thus positioned for convenience.

In Figure 36 is shown this same coil with its connections to other parts of the ignition circuit, including the breaker, the distributor and the reversing swich.

Figure 37 shows the construction of three types of Delco coils. The unit at the top has a condenser inside the coil case and a resistance unit on one end. The center coil is built without a condenser, that unit being mounted in the breaker. The lower drawing shows a coil having two secondary terminals for connection to two separate distributors firing two plugs in each cylinder for two-spark ignition.

The core of an ignition coil is generally made of lengths of soft iron wire, although some coils have a core of very thin sheets of soft iron laid side by side. To prevent eddy currents, the wires or sheets are insulated from each other by the scale and oxide naturally formed on their surface, and sometimes by being dipped into insulating varnish. The core is covered with an insulating covering of paper or fibre, over which is the primary winding.

The primary winding consists of from one to two hundred turns of enameled wire in most cases. Cotton or silk covered primary wire is seldom used because of the heat. Many coils have from 120 to 160 turns of this wire. The gauge size is usually number 21, 22, 23, or 24 for the primary. Each layer is insulated from the next one by a wrapping of insulating paper or cloth.

Most coils have their secondary winding wound around the outside of the primary, although a few are made with the secondary at one or both ends of the primary and directly on the core. With the secondary outside the primary, the secondary winding is shorter than the primary, and the primary is slightly shorter than the core.

The secondary winding in the average coil consists of from ten to fifteen thousand turns of number 38 or

number 39 enameled wire. Some coils have as high as thirty thousand or more turns of secondary winding, but these are now rare in ignition work. The

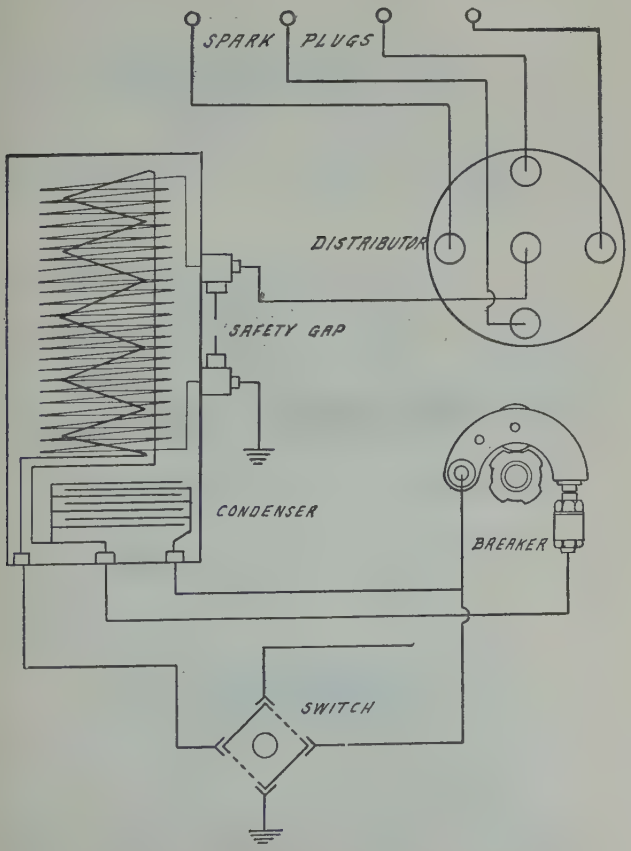


Figure 36.—Connection in Coil in Ignition Circuit.

different layers of the secondary winding are insulated from each other with one or more wrappings of insulating paper or silk between each layer and

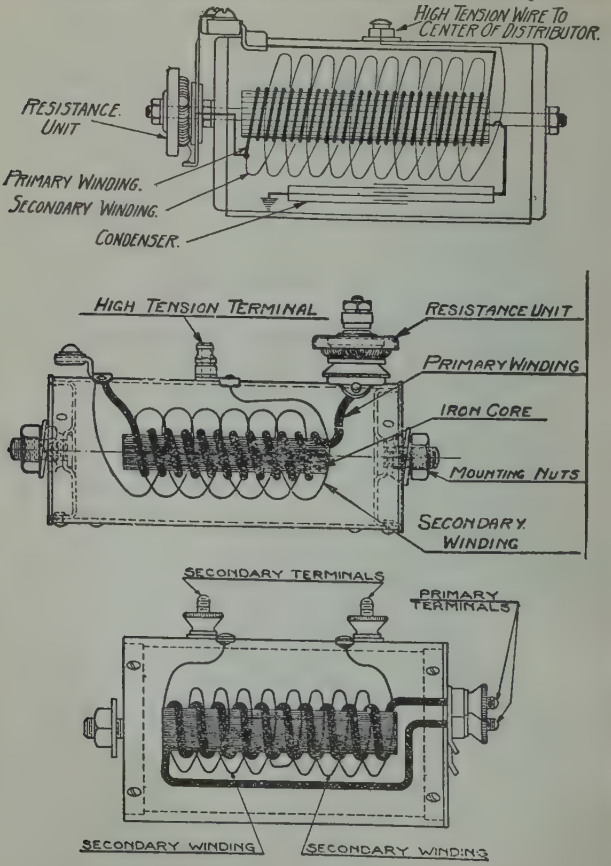


Figure 37.—Construction of Delco Coils.

the following one. In some cases the secondary winding is divided into two or more parts in series.

Both the primary winding and the secondary winding are filled with insulating wax under a vacuum so that all air is excluded from around and between the wires. After the windings are placed in the case of the coil, the case is often completely filled with some form of insulating compound, this also being put in under a vacuum so that all parts are thoroughly insulated. Other coils support the windings and connections inside the case without the insulating compound around them. Whether the case is filled with compound or not, the windings must be well insulated from other parts in the case by being wrapped with varnished cloth, or surrounded with pieces of fibre or mica.

The wires and connections inside the coil case should be soldered to their terminals and to each other where connections are made. The wires are often covered with a small tubing made of cotton, rubber, or waxed cambric to give additional insulation.

When the condenser is carried inside the coil case it must be well insulated from the secondary winding and wires, and from all other internal connections. This insulation is provided by wrappings of varnished cloth, or by sheets of fibre, mica or glass covering the condenser.

SPARK PLUGS

The spark plug is a device designed to carry the high tension current into the combustion space of the engine and there to allow the current to form an arc or spark between two points separated by a definite gap, the heat of this spark causing ignition of the fuel mixture to take place. The spark plug must

operate under the difficult conditions of extreme variations in temperature and pressure while at the same time preventing the improper escape of an electric current of thousands of volts pressure. While this unit is small and generally of simple construction it is among the most important and highly developed in the whole ignition system.

In its simplest form the spark plug consists of a shell threaded on its outside surface so that it screws into some part of the combustion space wall, and inside of this shell an insulating bushing through which passes a conductor called the central electrode

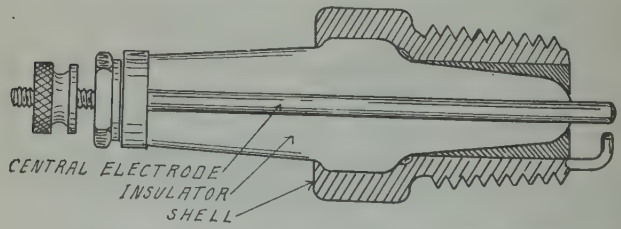


Figure 38.—Principal Parts of a Spark Plug.

and through which the secondary current enters the combustion space. These parts of the plug are shown in Figure 38. The design of the shells of various makes and types of plugs has been practically standardized and but little variation is found in the formation of the central electrodes. In the insulator and in the form of the ground electrode or lower end of the shell, designers have exercised their ingenuity to the fullest extent with the result that some remarkable constructions have been evolved.

Insulator.—Materials used in the building of insulators for spark plugs include porcelain, soapstone,

lava, mica and artificial stone. All of these materials have the common characteristics of resisting the passage of electric current and in varying degrees of resisting the action of heat and the effects of burned and partially burned oil and fuel mixtures. The two greatest foes of the spark plug are deposits of oil or carbon and accidental damage to the insulators and it has been with an idea of overcoming these obstacles to perfect working that the various departures in design have been brought into use.

Porcelain for use as an insulator is of very fine close grain and is finished with a coating to give a high gloss on which it is difficult for carbon deposits to accumulate and through which carbon and oil will not penetrate as long as the glaze is unbroken. This porcelain is made to successfully withstand very high degrees of heat and also to withstand sudden changes from heat to comparative cold. Porcelain has the two inherent disadvantages of liability to fracture from mechanical damage and of a coefficient or rate of expansion that differs considerably from the rate of expansion of the metal parts in which it is held. This difference in expansion gives rise to severe mechanical strains against which it is necessary to provide means for relief.

Mica insulators are formed from very thin sheets of this mineral, either wrapped around the central electrode to form a jacket or else cut into discs or washers which are placed one on the other with the central electrode passing through an opening in their center until a sufficient number have been assembled to form an insulator of the desired length. In some cases a combination of the wrapped sheet with the washers is used. After the insulating core has been

built up to size it is held together with pressure great enough to cause the whole number of mica discs to practically become one piece. The assembly of a mica core is shown in Figure 39 wherein the discs are supported at the bottom by a small metal plate fixed on the electrode and held in compression by a nut at the top.

Mica has the desirable quality of great mechanical strength and consequent freedom from breakage or cracking either from heat or accident and a mica plug will stand a great deal of abuse and still continue to

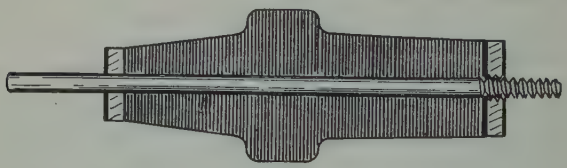


Figure 39.—Laminations in Ordinary Mica Core of Spark Plug.

do its work. Because of their mechanical strength and ability to pass through the greatest changes of heat and cold without fracture, mica plugs have been used rather extensively in air cooled engines which operate at temperatures a great deal higher than their water cooled counterparts.

The disadvantage of mica as an insulator lies in the fact that it is subject to a gradual penetration by the oil and carbon deposits which creep in between the discs or between the layers and strata of the mineral itself in spite of the greatest practicable pressure. With a new plug this tendency is well resisted, but as the action of the electrical, mechanical and thermal elements continues, there finally comes a time when

the foreign substances have crept in near enough to the central electrode to form a short circuiting path and at this time the insulating properties of the plug break down. This sort of failure gives rise to troubles which are many times of a very baffling nature because the plug is apparently in perfect condition and shows no defect when the spark is allowed to pass in the open air. Under compression, however, the high tension current takes the path through the oil and carbon between the layers of mica rather than across the air gap.

Lava and soapstone insulators combine much of the strength of mica with the high insulating properties of the porcelain. They also have some of the disadvantages of each in being subject to fracture easier than the mica and offering less resistance to the penetration of the carbon deposits than does highly glazed porcelain. The exact composition of these several insulators varies with the different makes of plugs and they are often given descriptive names to distinguish their make.

Shape of Insulation.—The thickness of the insulating core between the central electrode and the shell is always sufficient to prevent the passage of the high tension current through it provided the material is not broken or cracked at any point. The shape of the lower end of the core is determined with two objects in mind: to prevent the formation of a deposit of carbon over the surface and to provide a comparatively great expanse of surface between the central electrode and the shell over which any discharge must take place when this surface is covered with a layer of carbon, oil or moisture.

In Figure 40 are shown a number of forms of the

lower end of the core. That at A is the very generally adopted conical form. At B is a type which is well back in the recess formed by the shell with the idea of protecting the insulator from the direct action of oil. At C and D are shown variations of the petticoat type of construction in which any escaping current would have to travel over both the inside and

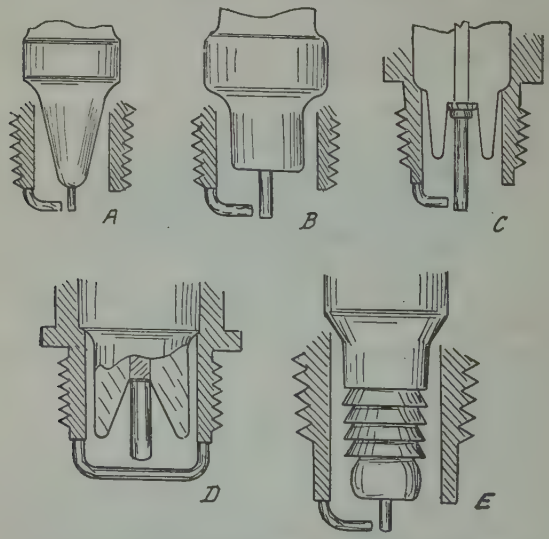


Figure 40.—Forms of Spark Plug Insulators.

outside surfaces of the lower end of the insulator before reaching the metal of the shell. The form shown at E provides a number of circular ribs which increase the surface and at the same time are designed to prevent the formation of carbon deposits due to the fact that the thin edges of the ribs attain a degree

of heat sufficient to burn away any collection of impurities.

Spark Plug Electrodes.—The ends or parts of the electrodes between which the spark takes place must be of a material that will resist the heat of the disruptive discharge and of such shape and size that they will not heat to incandescence and so cause preignition of the charge. The simplest and most generally adopted forms of electrodes are shown in Figure 40. A straight central electrode extends beyond the insulator and a short length of wire is set into the shell and bent with its end close enough to the central electrode to form the desired gap.

At one time a considerable number of plugs were provided with electrodes tipped with platinum or platinum alloys because of this metal's resistance to heat and corrosion. This practice adds greatly to the cost of the plug and lately the platinum has been generally abandoned in favor of nickel and various alloys of nickel and steel for the two electrodes. Nickel is one of the hardest of metals and is less fusible than iron. It is not altered by the action of the air or any common gases at temperatures ordinarily met with and forms a very satisfactory substitute for the more expensive platinum.

A number of plugs are made with the usual type of central electrode or with but slight modifications of this straight, small rod and with an extension of the lower end of the shell which partially encloses the sparking end of the plug and protects the end of the insulator while acting as the shell electrode. Three modifications of this type of plug are shown in Figure 41 in the upper row.

While a majority of spark plugs provide but one

gap across which the spark must jump, others are constructed to give two or more alternative paths or gaps. The method is shown by the lower drawings of Figure 41 as providing the shell with two or more bent-over electrodes somewhat similar to the single one generally found or by the use of some form of bridge or loop. No more than a single spark will pass at any one time in a multiple gap plug because the current will always select the path of least resistance and inasmuch as some one pair of points will always be a little

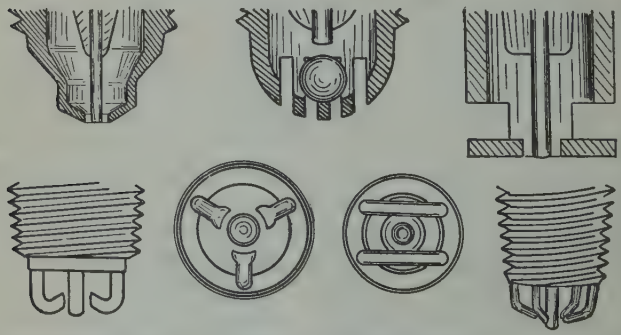


Figure 41.—Types of Spark Plug Electrodes. Top: Single Gap Forms. Bottom: Multi-Point Forms.

closer together than any other pair the spark will pass at these points until they have burned away or been bent apart so that some other set forms a gap of less resistance, when the current will take this new path. In this form of plug the short circuiting of any one gap will short circuit the whole plug because all of the current will then take this path of least resistance.

The shape of the points of the electrode between which the arc takes place has something to do with the effectiveness of the plug. It is a well understood

fact that an electric discharge will take place easier from a comparatively sharp point than from a surface that is flat or rounded. For this reason it would be desirable that the end of the electrode be rather pointed and of small section. On the other hand a small or pointed electrode will burn away much quicker than one with more body of metal so that a middle course, combining lasting qualities with fair freedom for discharge, must be chosen in the design. The pointing of the electrode could be carried to an extreme in which case the discharge would be of the brush type which does not provide the heat found in the sharp disruptive spark that is formed between fairly large points.

Spark Plug Gap.—The distance apart of the points in the spark plug is of great importance in properly firing the mixture. With a dynamo and storage battery as the source of current the spark becomes weaker with increase of engine speed in all except true open circuit systems and in these it maintains practically a uniform strength at all speeds. At high engine speeds the compression pressure is greater than at low speeds and the resistance between the electrodes is therefore greater with a fast running engine. With a magneto as the source of ignition current the spark is comparatively weak at low speeds and becomes stronger and better able to jump the gap as the engine speed and magneto voltage increases. In any case the gap at the plug must be small enough so that the lowest voltage produced with the engine at any ordinary running speed will be sufficient to pass across this space in the plug and produce an arc hot enough to cause good ignition.

For average conditions and in the average engine

the distance between the electrode ends, or the spark plug gap, should be between twenty-five and thirty thousandths of an inch. Under some conditions this gap might advantageously be reduced to twenty thousandths or increased to forty thousandths but these would be the extreme variations.

With battery ignition; should there be missing at low speeds the spark plug gap may be slightly increased in size, while for missing at high speeds the gap may be closed a trifle more. With magneto ignition the reverse is true; low speed missing calls for a smaller gap and high speed missing for a larger gap.

Shells and Threads.—The first spark plugs used in America were made with a metric thread because of the fact that the details of the first cars were copied from their foreign predecessors. This is a straight thread and the plug is provided with a shoulder which turns up tight against a finished surface around the opening in the cylinder wall and with a gas tight gasket of some form between the plug shoulder and the body of the cylinder. Metric plugs are now found in use on some motorcycle engines and airplane engines, on old American cars and on cars of foreign make.

Later cars, and some makes of cars up to the present time, use spark plugs having a one-half inch standard pipe thread. This is a tapered thread which is screwed into the cylinder opening until the tightness of the fit between the male and female threads makes a gas tight joint without the use of a gasket. Plugs with a half inch standard thread may easily be screwed into a hot cylinder so tightly that it is very difficult to remove them at a future time, especially when the engine has cooled. In this case a liberal

application of kerosene allowed to remain around the plug for some time will usually solve the difficulty. The tapered thread is more likely to be damaged by carelessness in handling than are the straight forms and one or two chipped threads on the plug or in the cylinder will generally cause a leak of the compressed gas.

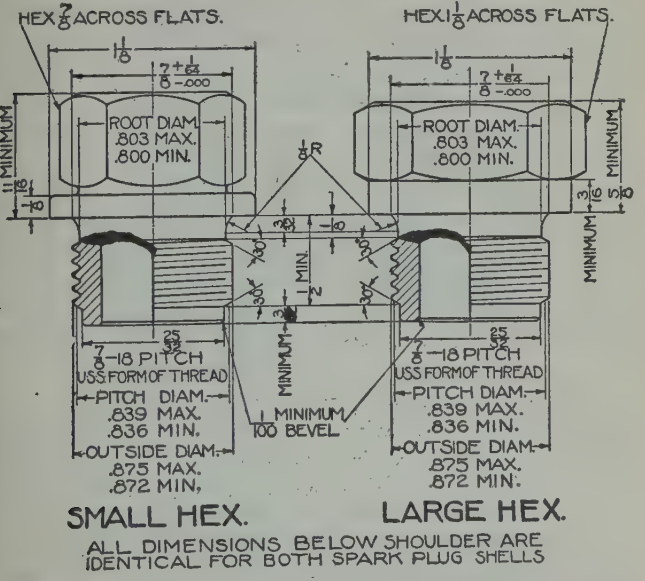

HEX 7/8 ACROSS FLATS.
HEX 1 1/8 ACROSS FLATS.
ROOT DIAM. .803 MAX. .800 MIN.
ROOT DIAM. .803 MAX. .800 MIN.
MINIMUM
MINIMUM
1/8 R
7/8-18 PITCH USS FORM OF THREAD
PITCH DIAM. .839 MAX. .836 MIN.
OUTSIDE DIAM. .875 MAX. .872 MIN.
MINIMUM 100 BEVEL
7/8-18 PITCH USS FORM OF THREAD
PITCH DIAM. .839 MAX. .836 MIN.
OUTSIDE DIAM. .875 MAX. .872 MIN.
SMALL HEX.
LARGE HEX.
ALL DIMENSIONS BELOW SHOULDER ARE IDENTICAL FOR BOTH SPARK PLUG SHELLS

Figure 42.—Dimensions of Standard Spark Plug Shells (Society of Automotive Engineers).

Two modifications of an American standard spark plug shell have now been adopted, both known as the S. A. E. (Society of Automotive Engineers) Standard. The two kinds differ only in the size of the hexagon part above the threads; the one called the

large hexagon being 1⅛ inches across the flats and the small hexagon being ⅞ of an inch across the flats. The outside diameter over the threads is ⅞ of an inch and there are eighteen threads to the inch of length. The plug is therefore oftentimes called a ⅞″-18. The S. A. E. plug has a straight thread and therefore requires the use of a gasket in making a gas tight joint. This gasket may be a separate member or may be formed over a fillet on the shell so that it is not removable. The dimensions are shown in Figure 42.

Separable and Non-Separable Plugs.—The insulating core through which passes the central electrode may be permanently fastened into the spark plug shell, in which case the plug is of the non-separable or solid type, or else the core may be held in place by means of a packing nut and gaskets so that the center assembly is easily removable for cleaning or replacement. This latter type is called a separable or two-piece plug. Both constructions are shown in Figure 43.

The non-separable plug has its insulating core placed in the shell with a gasket between the lower shoulder of the core and the seat in the shell. The upper shoulder of the core is pressed down by the metal of the shell or by some form of tapered wedge and the metal of the shell above this shoulder is beaded over to make a permanent and gas tight joint. The plug of this construction has the advantage of permanent alignment for the electrodes, which fixes the gap distance, and of permanent gas tightness. Its disadvantages are difficulty of cleaning the insulator and impossibility of renewal of the core and central electrode without an entire new plug.

The separable plug carries its insulating core be-

tween two gaskets, one between the lower shoulder of the core and the seat of the shell and the other between the top shoulder and the packing nut which holds the core in place. The core and central electrode may be removed from the shell by first unscrew-

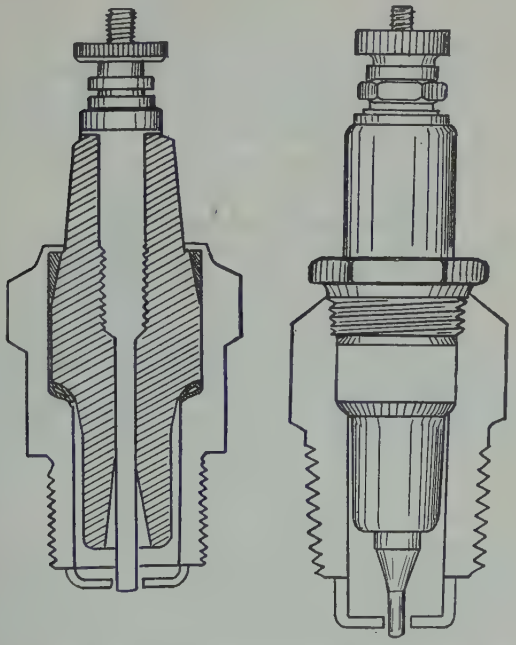


Figure 43.—Spark Plug Construction. Left: One Piece Plug. Right: Separable Plug.

ing the packing nut; and after removal of the insulator its surface may be easily cleaned of any accumulations of carbon or oil. The disadvantages of this type are found in the danger of misalignment of the gap points

on replacement and the danger of breakage of the core because of screwing the packing nut into place too tightly or else not tightly enough so that the core is left loose in the shell.

In addition to their making gas tight joints, gaskets are necessary in most forms of plugs because of the difference in the rates of expansion for the metal of the shell and the material of the insulator. Porcelain and many kinds of insulating stone have widely different coefficients of expansion from the steel and in separable plugs with insulators of these materials great care should be exercised not to turn the packing nut down too tightly because this will result in breakage of the core as soon as the engine warms. A packing nut should be turned into place just tightly enough to hold the core firmly and to prevent the escape of gas, but no tighter under any circumstances.

Spark Plug Location.—No form of spark plug will give the results of which it is capable if its location and setting in the cylinder are not correct. In order that an engine may run efficiently the time required for the spread of the flame through the mixture should be as short as possible, and to secure this result the spark plug gap should be located within the combustion space and not in a pocket or recess.

If the plug is so located that its points are placed in a recess or hole that communicates with the combustion space, as will be the case with a short plug set in a thick valve cap, dead gas will accumulate about the electrodes and cause missing and slow combustion. With the gap inside the combustion space proper, the spark comes into contact with fresh clean gas and the flame will spread with maximum rapidity. Such a correct setting is shown at the left in

Figure 44, while at the right is shown an incorrectly pocketed plug.

It follows that the spark plug should preferably be located in the immediate neighborhood of the intake valve in such a manner that it will be surrounded by the fresh gas that enters during the intake stroke. If the plug is located near the exhaust, rather than the intake valve, there is a possibility that the dead exhaust gas collecting around the points will cause missing and inefficiency.

In order to get the best results the plugs should

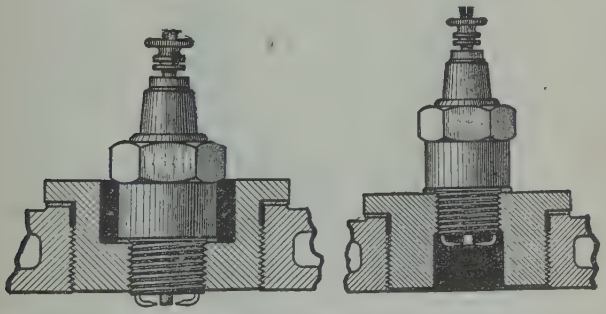


Figure 44.—Spark Plug Mounting. Left: Correct. Right: Incorrect (Bosch Magneto Company).

be so set in the cylinder that cooled metal is in close proximity to the sparking points as this setting will eliminate overheating of the plug electrodes with the consequent danger of preignition due to red hot metal. This requires that the plug be set into a portion of the cylinder that is at least fairly well cooled by the water jackets in a water cooled engine.

On many engines the spark plug is set into the cylinder wall in such a position that it passes through

the water jackets and an extra long bodied plug is required in order to prevent harmful pocketing of the gases. With such a design the electrodes, and in many cases a part of the end of the shell, extend beyond the threaded portion of the plug. There is then danger of the electrodes becoming excessively hot or that the metal of the shell will allow warping and consequent change in the size of the gap. The effect depends on the position of the plug with reference to the cooling water jackets.

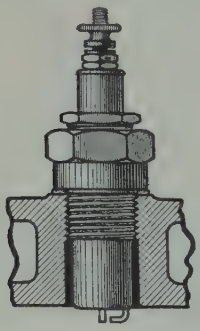


Figure 45.—Extension Plug.

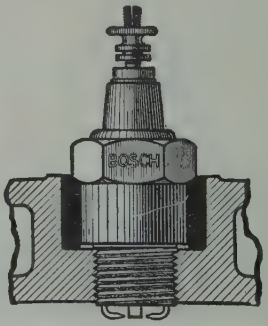


Figure 46.—Plug Set in Cap.

Spark plugs are set either into the valve caps, into the sides of the cylinder walls, or into the head of the cylinder. When set through the head or walls the plugs often pass through part of the water jacket, and the opening for the plug is then quite long. To avoid placing the plug in too deep a pocket, a plug with an extended shell as shown in Figure 45 may be used, or a plug with a short shell may have long extensions of the electrodes so that the spark is formed well inside the combustion space. With the

plug set into a screw cap passing through a rather thick wall, the cap itself may be formed with a deep recess as in Figure 46.

IGNITION WIRING

Cable.—Ignition wire or cable is usually designated by the name of the current it is designed to carry. Primary wire for conducting the primary or low tension current is made with a comparatively large copper conductor and with a small thickness of insulation over the copper. This form is most satisfactory because the large area of conductor carries the low pressure current with but slight loss in voltage due to the resistance of the cable. Secondary wire has a smaller copper conductor than has the primary but has a comparatively thick insulating covering. The small wire carries the secondary current because this current is of very low amperage and the slight voltage loss is of little consequence when dealing with thousands of volts pressure as is the case here. The heavy insulation is required because of the high voltage which would force the current through any lighter covering rather than sending it across the high resistance gap at the spark plug.

All ignition cable is of the flexible variety, made up of a conductor consisting of a number of strands of very fine wire, the number and size of these strands being sufficient to provide the necessary conducting ability. Such a cable is called a stranded cable. Over this conductor is generally placed an insulating cover of compositions of rubber, although much ignition cable is in use having its insulation composed of layers of strip linen or cotton wound around the conductor and then covered with woven fabric. In

some cases this cloth insulation is combined with one or more layers of rubber insulation also. Such a cable is called braided or fabric covered. Methods of fastening cable ends are shown in Figure 47.

Primary cable is often made with two or more conductors, each covered with its own insulation, and

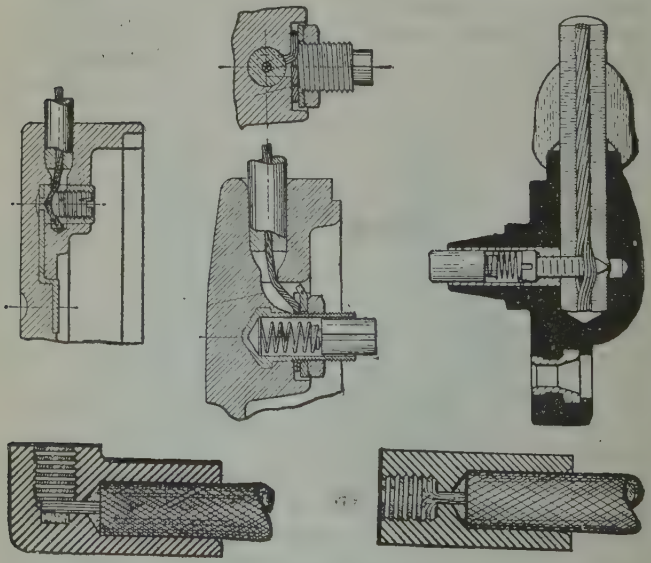


Figure 47.—Methods of Fastening Wire Ends (Bosch, Eisemann and Splitdorf).

the whole enclosed with an outer covering of fabric and additional insulation. Such cables, called duplex, triplex, etc., according to the number of separate conductors in the cable, are used for lines requiring that several circuits, or the positive and negative sides of one circuit, be carried between points

which allow the opposite ends of the several lines to be close to each other.

Primary Cable.—Primary cable may be constructed according to either of two methods, each method being a standard recommended by the Society of Automotive Engineers. Class "B" cable is provided with an insulating covering composed of rubber compound and fabric. The rubber is first covered either with an overlapping strip of varnished cambric, or a cotton braid, so saturated as to make it oil and moisture proof. This first fabric is then covered with an outer braid of strong protective character, preferably glazed, and treated with at least two coats of insulating varnish. The rubber itself is 1/32 inch thick. Such cable will withstand a pressure of 1000 volts for one minute.

Class "C" primary cable will withstand 1500 volts for one minute. The insulation of this class of cable includes either two or three layers of varnished cambric tape, then a closely woven cotton braid which is treated to make it oil and moisture proof and finally an outer braid of a protective nature which is treated with at least two coats of insulating varnish.

Secondary Cable.—Secondary cable may be made with plain rubber insulation, then having an outside diameter of either seven or nine millimeters; or it may be made with an additional covering of cotton braid, when the outside diameter will be either 5/16 or 25/64 of an inch.

Good secondary cable will withstand 12,000 volts for five minutes after the cable has been in water for twelve hours and while it is still immersed. A one foot length of such cable will withstand 20.000 volts for five minutes.

The life of secondary cables may be tested as follows: Remove the insulation from each end of a five foot length of the cable, solder one end of the cable to one end of a steel rod of approximately the same diameter as the cable, wrap the cable tightly around this rod and solder the other cable end to the rod so that the tight wrapping will be maintained. In this condition the cable should be exposed to the weather. If the insulation is not properly compounded or vulcanized, deteriorating effects, such as hardening, becoming brittle and cracking, will develop in from one to three months.

REVIEW OF CHAPTER III

THE IGNITION CIRCUIT

A closed circuit ignition system uses a breaker in which the contacts are normally held closed by the spring until they are separated by the cam. This is the type generally used.

An **open circuit** system has its contacts held apart until closed by the cam.

The **resistance unit** is a short length of iron wire formed into a coil and connected between the battery or switch and the primary winding of the coil. By heating and increasing its resistance, the resistance unit prevents too great a flow of current through the coil should the switch be left closed with the engine idle.

The **safety spark gap** is placed between some point in the secondary circuit and ground. Its resistance is more than that of a normal spark plug gap, but smaller than that of the secondary insulation. With an open circuit in the secondary lines, the high tension current passes to ground across this gap in place of puncturing the insulation.

An **ignition coil consists of** a core, a primary winding, a secondary winding, their insulation, and the necessary connections and supports.

The **primary of a coil** consists of from one to two hundred turns of heavy wire, the **secondary** of from ten to fifteen thousand turns of fine wire.

A **spark plug consists of** the central electrode, the insulator, the shell and shell electrode, and the necessary gaskets and terminals.

Insulators are made of glazed porcelain, mica, or compositions of artificial stone. **Electrodes** are generally made of nickel steel.

There will be but **one spark at one time** in any plug, regardless of the number or shape of the gaps, unless two **gaps are in series with each other.**

The **spark plug gap** should be between .025" and .030" under usual conditions. With battery ignition, high speed missing calls for a smaller gap, low speed missing for a longer gap. With magneto ignition, high speed missing calls for a larger gap and low speed missing for a smaller gap.

The **S. A. E. spark plug thread** is 7/8 inch diameter, has 18 threads to the inch, and is straight. The **half-inch thread** is a taper thread, the same as cut on the outside of a half-inch pipe. It has 14 threads to the inch and tapers 1/16 inch per inch of length.

Extension plugs should be used when carried in pockets.

Ignition cable is classed as primary or secondary, depending on which circuit it is to be used in.

CHAPTER IV

IGNITION TIMING

PRINCIPLES AND REQUIREMENTS

Timing the ignition spark is done by setting the breaker cam, the breaker shaft, or the housing, in such a position that the spark will occur at or near top dead center following the compression stroke.

The breaker cam is positively driven from the engine, through gears, chains or shafts, and with battery ignition systems it runs at cam shaft speed, making one complete revolution for each two revolutions of the crankshaft.

During the complete revolution of the breaker shaft there must be one spark for each of the cylinders because each cylinder will have one firing stroke during this time. It therefore follows that the breaker contacts must open once during the revolution of the breaker shaft for each cylinder to be fired. Each lobe or projection on the breaker cam causes the contacts to open once so that with a single set of contacts there must be as many lobes or projections on the cam as there are cylinders to be fired by this breaker, each of these lobes causing a spark by opening the contacts. With the ignition breaker shaft and its cam traveling at engine crank shaft speed, or twice as fast as

the engine valve cam shaft, the breaker cam will require just half the number of lobes that the slower traveling type just described would require. Traveling twice the number of revolutions in the same length of time relative to the engine cycle, half the number of cam lobes will do the same work.

In the last chapter two different types of breaker were described, the closed circuit and the open circuit. It was also shown that the closed circuit type of breaker opens its contacts when the forward side of the cam lobe acts on the contact carrying arm,

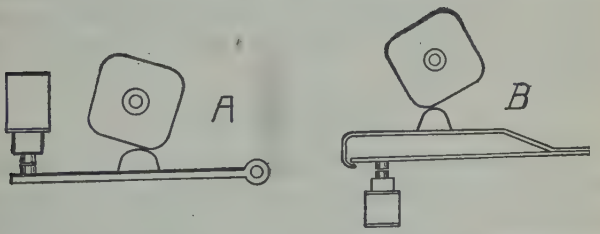


Figure 48.—Time of Contact Opening with Closed Circuit (left) and Open Circuit (right) Type of Breakers.

while in the open circuit type the contacts are allowed to open under the action of a spring when the cam lobe passes out from under the bumper which moves the breaker arm. These actions are shown in Figure 48. At A is a closed circuit type of breaker with its cam in position to just open the contacts with continued rotation. At B is the open circuit type with its cam also in position to allow the contacts to open. To set or time the breaker shown at A the cam would be turned in the direction of its normal rotation until one of the lobes just touched the breaker arm bumper, as in this position the con-

tacts will be pushed apart with the slightest further motion and the spark will therefore take place whenever one of the cam lobes reaches this position. In timing the breaker shown at B the cam would be turned in the direction of its rotation until one of its lobes had pressed against the bumper carrying arm which would cause the contacts to close, and the cam would then be turned farther in this same direction until the cam lobe was just passing from under the bumper as shown in the figure. At this time the contacts would be separated by their spring and the spark would therefore take place each time the cam lobe reaches this position with reference to the breaker arm.

TIMING METHODS

Various means are provided to allow the workman to bring the breaker cam into the desired position. With some makes and types of equipment the cam itself may be loosened or removed from the shaft which carries it, then moved to the correct position for contact opening and again locked in place with reference to the shaft. In other designs the shaft which carries the breaker cam is so constructed that it may be freed from the driving connection with the engine either by means of a sleeve joint, a special coupling or other device that suits the ideas of the designer. The breaker shaft is, in such a type, turned with the cam in place on the shaft until the cam has been brought to the desired position. Still other forms arrange that the breaker arm and contact points be rotated around the breaker cam shaft until the operating means on the arm is brought into such

relation to the breaker cam that any rotation of the cam after this position has been reached will serve to open the contacts.

To bring the breaker cam into its position for timing it will be necessary to move the cam alone, or else the cam with its shaft, in the same direction that these parts are driven by the engine while in operation. In addition, any mechanical play or lag in the several parts should be taken up as it would be with the engine running. The cam or shaft would therefore be moved in a clockwise or righthand direction in both A and B of Figure 48, this being the supposed direction of rotation. In case it is only possible to move the breaker or ignition head housing, rather than the cam or its shaft, the housing must be moved in a direction opposite to that of the shaft and cam rotation. Reference to Figure 49 will make clear the fact that rotation of the cam in the direction indicated by the small arrow on the cam would have exactly the same effect in bringing the cam and bumper into certain relative positions as would be produced by moving the housing with the breaker contacts in the opposite direction, this opposite direction being indicated by the larger arrow just inside the breaker housing. In other words it is required that the cam be moved forward or the housing be moved backward until the cam lobes are properly placed with reference to the breaker arm bumper.

Timing Procedure.—Timing the ignition is the operation by means of which the breaker mechanism and the distributor are brought into proper relation to the pistons of the various cylinders to cause the

passage of the spark at the correct instant during the engine's cycle. Because the breaker cam is designed to accommodate the number of cylinders on the engine with which used and because the distributor is likewise built for this same number of cylinders, timing the ignition for any one cylinder will correctly time the operation of the breaker for

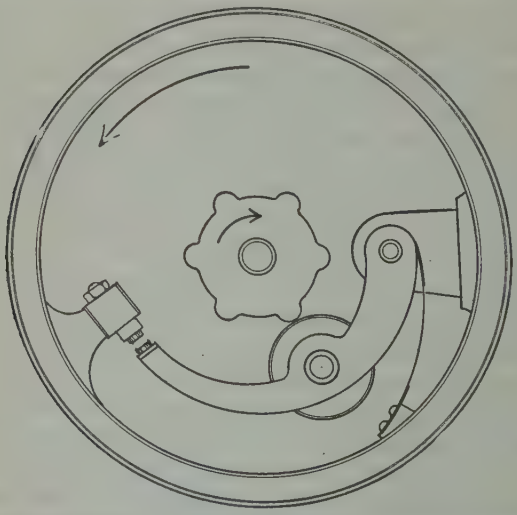


Figure 49.—Direction of Movement for Cam or for Housing in Spark Advance.

all other cylinders and will also bring the distributor into position so that placing the rotor and the spark plug wires is all that is left to do.

Timing should be done by placing the piston in one of the engine cylinders at that point in the cycle at which the ignition spark should take place under certain conditions of advance and retard. While the

results will be exactly the same regardless of which one of the cylinders is selected for the operation, cylinder number one which is at the front of the car is usually chosen and specified. It should be understood that it is just as well to use number two or any other cylinder should they be more accessible than number one. Timing may be done with the parts in position for a fully retarded spark, for a spark half way advanced or for a fully advanced spark. It is generally best, however, to use the proper positions for a fully retarded spark because it is quite necessary that a sufficient retard be allowed in order to avoid too early ignition with the attendant dangers to the mechanism or to the operator if the cranking is done by hand. With the necessary retard allowed for, the range of advance will be determined by the construction of the breaker and the arrangement of the advance and retard rods and levers. This advance will then, in practically all cases, be ample for all operating conditions, while were the advanced position used in timing, the required retard might not always be secured. From the above explanation it will be clear why number one cylinder and the fully retarded positions are selected in giving timing instructions. In the chapters devoted to complete descriptions of the several makes and types of ignition apparatus specific instructions are given for timing and these should always be followed when given. In the absence of specific instructions for the particular equipment being handled the following general directions may be followed:

First: Bring the piston of number one cylinder to top dead center between the compression and firing

strokes. The point at which the piston is in this position (top dead center) may be determined in any one of several ways. In case the flywheel is marked these indications may be used. The marking may specify the position by such characters as "TC 1 & 4" (top center for pistons one and four in a four cylinder engine), "C 1 & 6" (top center for pistons one and six in a six cylinder power plant) or any other markings whose meaning may be easily understood. At one side of, or between the characters of such a marking, there will be found a line drawn from front to back of the flywheel and this line should be brought directly on top of the flywheel or directly underneath a pointer or arrow which is fastened to some stationary part of the engine.

If the flywheel of the engine is not marked it will be possible to watch the piston's movement by removing one of the valve caps, a spark plug, a cylinder head plug, a pet cock or any other part which will provide an opening into the combustion space. With such an opening the piston may be watched with the aid of an artificial light or its movement may be determined by inserting a wire or rod through any available opening and observing the rise and fall or movement of this rod as the crank is slowly turned.

It is not only necessary that the piston be brought to top dead center, but that it be brought to the top center between the compression and power strokes, not to the center between the exhaust and intake strokes. At the top center between compression and firing, the combustion space is filled with a compressed mixture of fuel gas and air ready for burn-

ing and it is at this time that the spark must take place. At the opposite top center, following the exhaust stroke, the cylinder's combustion space is filled with dead gas which would not ignite.

The proper top center may be determined by observing the action of the valves for the cylinder being used for timing. With the valve stems or springs uncovered, the crank should be turned slowly until the exhaust valve of the cylinder being timed is seen to open. With continued turning of the crank this valve will then close and the inlet valve of the same cylinder will immediately start to open. The point during the revolution of the crank at which the exhaust closes and the inlet opens is very near top dead center, but this is the center between exhaust and intake which not wanted for ignition timing. One full turn of the crank will then bring the piston into the correct position between the compression and power strokes. As the piston nears the correct position the crank should be turned very slowly while the piston movement is checked as described. When the upward motion ceases the top center has been reached and the cranking must be discontinued before the piston again starts down.

The above method of bringing the piston into position starts with the opening of the exhaust valve which is almost two whole turns before the desired top center will be reached. While this may seem to entail an uncalled for loss of time, it is recommended because it gives the operator something which is easily seen and easily recognized (the exhaust valve opening) to start with. It is of course true that an experienced workman, used to timing ignition

devices, might start from whatever point in the cycle he found the piston at and secure the same results, still the slightly slower way is generally best because it is the sure way. Should the inlet valve be observed to just close when the engine is first cranked it will only be necessary to turn until the piston is at the next top center which will be the one between compression and firing. With the piston brought into this position, by whatever method, it should be allowed to remain stationary, and under no circumstances should the crank shaft be turned the least bit until the breaker setting has been made.

Second: After placing the piston, the breaker advance and retard lever should be connected to its operating rods and these rods should be connected with the parts leading to the hand advance lever on the steering wheel or column. The spark control lever is generally the shorter one of a pair. With the connections made, the hand lever should be moved one way and the other while watching the movement of the breaker housing or of the breaker advance lever. With the hand lever moved from its retarded position to the advanced position (away from the operator in most cases) the breaker housing should move in a direction *opposite* to that in which the breaker shaft and cam revolve when driven by the engine. If the breaker housing does not revolve, then the breaker mechanism should be watched and the part of the breaker which carries the arm and the movable contact point should revolve in a direction the opposite of that in which the shaft turns. Should the breaker housing or base

plate move in the same direction as the shaft turns with the hand lever moved from retard to advance, either the connections are wrongly attached or else the direction of the hand advance is the reverse of that assumed.

In case the breaker cam, rather than the housing or base, is found to move; it should travel in the direction driven by the engine for advance and in the reverse direction for retard of the spark.

There should be little if any lost motion in the connections, rods and levers. If lost motion exists it should be taken up during the timing operations by moving the advance lever on the breaker in the direction of advance by hand until all slackness is taken out of the connections. When ready to proceed with the timing after having checked the items mentioned, the hand advance lever should be moved from the fully retarded position about one-tenth to one-four of its full travel toward the fully advanced position. With the lever thus moved and the lost motion taken up, the breaker housing should be allowed to remain in this position.

Third: The cam or the breaker cam shaft should be set to just open the contacts. If the breaker is so constructed that the cam may be loosened from its shaft this should now be done. If the breaker cam is permanently secured to its shaft it will generally be found that the shaft is in two parts, one part carrying the breaker cam while the other part is attached to and driven from the engine. These parts of the shaft may be fastened together for driving purposes by means of one or more set screws in a sleeve, by a clamping joint or by any one of several

types of adjustable couplings. By whatever means fastened together, the two parts of the shaft will have to be disengaged for timing purposes.

If neither of the above conditions obtain; that is, if the cam is secure on its shaft and the shaft is not divided, it will be necessary to take the breaker shaft driving gears out of mesh or to uncouple the driving chain if this method of drive is used. In any event the parts driving the breaker cam shaft should be disconnected so that movement of the breaker cam is possible without moving the piston and crankshaft of the engine. It is possible that the breaker cam and its shaft cannot in any way be disconnected from the engine driving parts and in this case it will be necessary to complete the timing by changing the length or relative positions of some of the advance and retard connections to allow turning of the breaker housing rather than turning of the cam. This condition is rare and will not be immediately considered because of the possible confusion in the following instructions.

With the breaker cam free to revolve it should be slowly turned in the direction it runs during the engine's operation until the contact points are seen to close and then to just separate. The cam should remain in the position at which the contacts barely start to separate because it is at this instant that the spark passes. With the cam, the control connections and the piston in the positions described the cam shaft drive should be secured so that this relation will be maintained. In some types of equipment one particular spark plug wire from the distributor is supposed to lead to the plug in number one cylinder,

the distributor cap being generally marked with the numeral "1" if this is the case. In such an event it will be necessary to turn the cam or the cam shaft in the breaker until the distributor rotor, when put in place, will carry the high tension current to the terminal thus marked. With the rotor brought to this position approximately, the cam may then be slowly turned in the direction it will be driven until the contacts just commence to separate. As far as the breaker, and the instant at which the spark takes place, is concerned the ignition has now been properly timed and it only remains to take care of the distributor and the wiring to the spark plugs.

The circuit tester described in Chapter VIII, Part I, may be conveniently used in timing to determine the instant at which the contacts separate without depending on the eye to note this movement. With all external low tension wiring connections removed from the breaker one of the leads from the circuit tester should be connected with the breaker terminal which leads to one of the contact points. The remaining line from the circuit tester should be placed in contact with the metal of the engine near the breaker if the other breaker contact is grounded (the usual practice) or, in case both sides of the primary circuit are insulated, the second circuit tester line should be touched to the breaker terminal which connects with the second contact point. With the contacts closed the test lamp will now light and during the operation of timing, the breaker cam or housing may be moved as described until the lamp lights, indicating that the contacts are together, and then moved until the lamp goes out which indicates

that the contacts have opened and that this is the position in which the breaker will cause a spark.

FIRING ORDERS

It is necessary to know the order in which the cylinders of an engine fire so that the wires from the distributor to the spark plugs may be properly placed. Crankshaft arrangements and their corresponding firing orders are shown in Figure 50. Cylinders are numbered, starting with 1 at the front end of the car. V-type engines with two rows of cylinders indicate those on the right hand of the driver by *R* and those on his left by *L* following the number which indicates the cylinder.

Looking at the four-cylinder crankshaft, it will be seen that one-half revolution after number 1 piston is at top center, pistons 2 and 3 will have come to top center. Therefore, after number 1 fires, either 2 or 3 will fire next. All four-cylinder engines fire in either the order 1-3-4-2 or 1-2-3-4, no other orders being possible with this crankshaft. The arrangement of terminals around a four cylinder distributor is shown in the small circle; reading one direction giving 1-3-4-2, while the other direction gives 1-2-4-3.

V-type eight-cylinder engines use the same form of crankshaft as used with a four-cylinder, but attach two connecting rods on each crank pin. The four cylinders in each block fire in either of the two firing orders used for four-cylinder engines, both sides always using the same order. Firing alternates from one side to the other and in specifying the firing order the numbering usually starts with number 1 on the left (1-L). Four firing orders are in use, these being shown by the circles representing distributor

terminals on which the firing orders may be read either way around. The orders are:

1L-2R-3L-1R-4L-3R-2L-4R
1L-4R-2L-3R-4L-1R-3L-2R
1L-4R-3L-2R-4L-1R-2L-3R
1L-3R-2L-1R-4L-2R-3L-4R

There are two arrangements of six-cylinder crankshafts. In one type, the crank for number 2 cylinder extends to the left with number 1 at the top; and in the other type number 2 throws to the right. With the left hand throw shaft the firing order is:

1-5-3-6-2-4

With the right hand throw shaft the order is:

1-4-2-6-3-5

Twelve-cylinder V-type engines use six-throw crankshafts with two connecting rods on each crank. Two firing orders have been used with these engines, both being shown in the circles. They are:

1L-2R-5L-4R-3L-1R-6L-5R-2L-3R-4L-6R
1L-3R-4L-5R-2L-1R-6L-4R-3L-2R-5L-6R

Engines with eight cylinders in a line use either of two types of crankshafts. One type is like two four-cylinder shafts joined together with one of them set at ninety degrees from the other. On the Duesenberg car this shaft has the following firing order:

1-5-3-7-4-8-2-6

Another eight in line crankshaft is like two four-cylinder shafts with one of them placed at a ninety

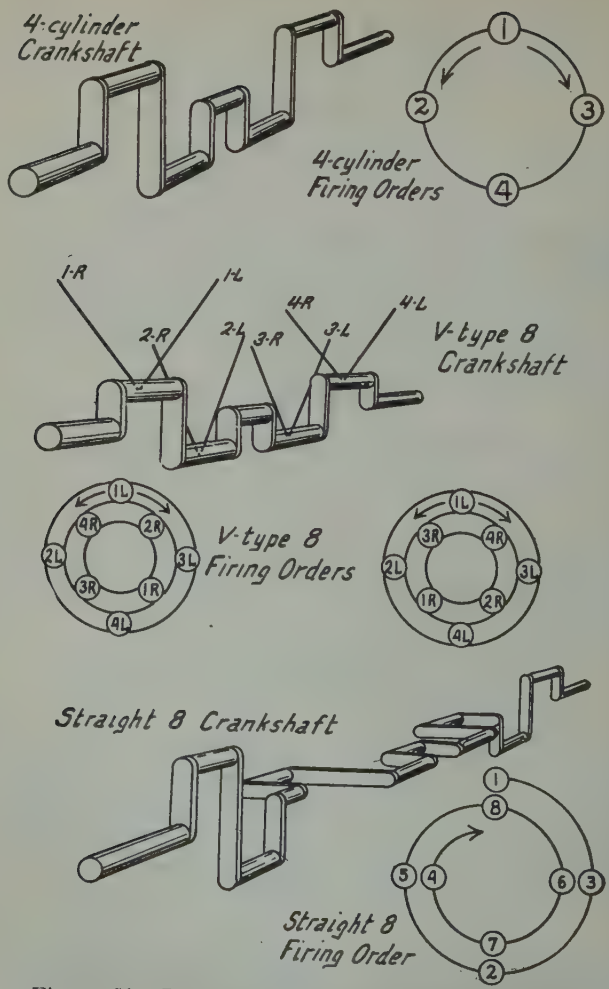


Figure 50.—Firing Orders for 4-cylinder, V-type 8, and Straight-8 Engines.

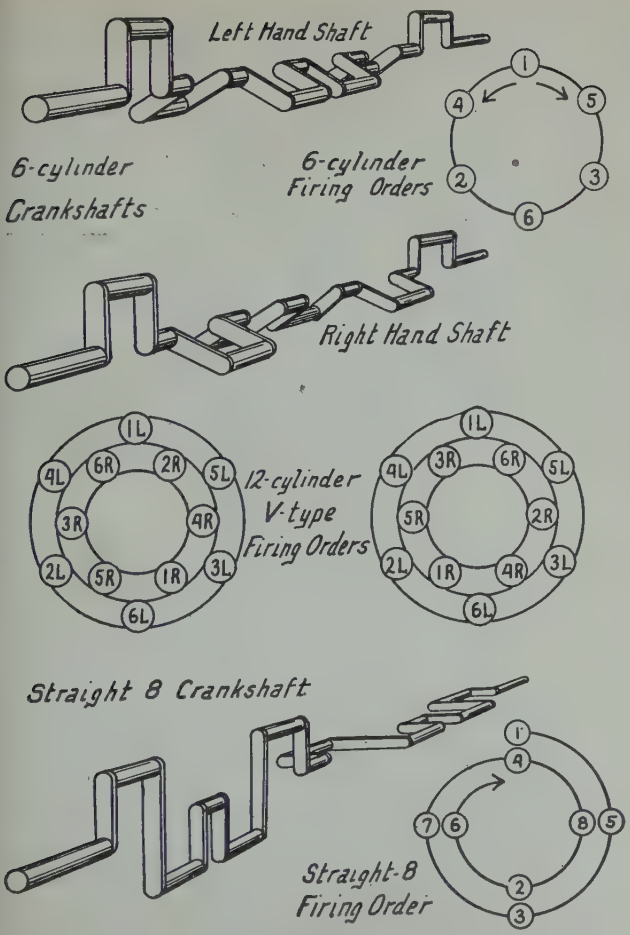


Figure 50.—Firing Orders for 6-cylinder, 12-cylinder and Straight-8 Engines.

degree angle between the two halves of the other. On the Packard car using this type of shaft the firing order is:

1-3-2-5-8-6-7-4

Of the four-cylinder firing orders, 1-3-4-2 is used on more makes of cars than 1-2-4-3. Of the V-type eight-cylinder orders, the one most used is 1L-2R-3L-1R-4L-3R-2L-4R. Of the six-cylinder firing orders, 1-5-3-6-2-4 is more generally used than 1-4-2-6-3-5. Of the two V-type twelve-cylinder firing orders, the one more commonly found is 1L-3R-4L-5R-2L-1R-6L-4R-3L-2R-5L-6R.

Determining the Firing Order.—A large number of engines have their firing order marked on the valve spring cover or on some other easily seen place on the engine. If an engine has no such markings, the easiest way to determine which firing order is used is to watch the valves open and close.

With the valve springs and stems uncovered, the rise and fall of either the inlet valves or the exhaust valves may be watched as the engine is slowly cranked by hand. The valves, of course, operate in the same order that the engine fires. Cranking should continue until number 1 valve (either inlet or exhaust) opens. Then the same valve (inlet or exhaust) should be watched for the next cylinder that may fire. In a four-cylinder engine this next cylinder must be either 2 or 3 and in a six-cylinder engine the second valve must be either 4 or 5. The remaining valves then open in the same order the engine fires, but the second valve indicates the firing order with either a four-cylinder or a six-cylinder engine. It is advisable to memorize the two different firing orders for four-cylinder and for six-cylinder engines.

It will be noticed that with a four-cylinder distributor numbered as in the circle of Figure 50, reading one way around gives one firing order and reading the other way around gives the other order. This same rule applies to the six-cylinder orders.

With a V-type engine it may be seen that the firing order of the cylinders in one block, when counting from front to back, will be the same as the firing order of the opposite block, reading from back to front. With the eight-cylinder V-type engines, reading one way around the circles will give one firing order and reading the other way around will give another order. Becoming familiar with some of these peculiarities of the various orders of firing will make it easier to apply the necessary rules in wiring the distributor to the spark plugs.

DISTRIBUTOR WIRING AND TIMING

After the opening of the breaker contacts has been properly timed for the engine it will be found that with the distributor rotor in position on its shaft or gear the distributor segments, brushes or pins will be in such relation to the rotor that the secondary current passing upon opening of the contacts will flow to one of the terminals on the distributor cap. If the timing of the breaker has been done by bringing the piston of number one cylinder to top firing center, then a wire should be placed between this distributor terminal to which the rotor sends the current and the spark plug in number one cylinder.

It is now necessary to observe in which direction the distributor rotor turns when the engine is running or is being cranked. This direction of revolution will bring the rotor into position on the next

opening of the breaker contacts to send the high tension current to a distributor terminal on one side or the other of that terminal which has been connected with the spark plug in cylinder number one. This next distributor terminal to receive the current should be connected with another wire to the spark plug of the cylinder next to fire according to the firing order of the engine being worked on, an explanation of how to determine this firing order having already been given. With further turning of the rotor as the engine is cranked the current will be led to the next terminal in order around the distributor cap and this terminal should then be connected with the third cylinder to fire. This same method should be followed, connecting the wires from the spark plugs in the order of the firing on that engine with the remaining terminals on the distributor in their order around the distributor cap and in the direction of the rotor's turning while in actual operation.

It will be noticed by observing the construction of any distributor that the rotor will deliver its current to the connection for one of the terminals during a considerable part of a revolution. That is to say, the rotor might be turned some distance either forward or backward and still pass the secondary current to the terminal connection without the necessity of having this current pass across any additional gap between the rotor and the terminal connection. This construction is adopted to allow for the advance and retard of the breaker because this advance and retard will cause the spark to pass either earlier or later in the turning of the distributor.

In Figure 51 this construction is shown by a breaker cam and contacts together with a distributor rotor making connection with a stationary terminal connection in the distributor cap. At the upper left is shown the fully retarded position, with the breaker cam just about to open the contacts and with the distributor rotor segment making connection with the terminal at the extreme rear end of the rotor's segment. As the breaker housing is moved to its advanced position the arm L and its contacts travel around the cam in a direction opposite to that in which the driving shaft turns until the parts are as at the upper right. The spark will then take place with the distributor rotor not so far around in its travel but in the right hand position where the rotor segment makes connection with the terminal at the extreme forward end of the segment. The distributor rotor is carried by the same shaft that operates the cam and of course turns in the same direction and at the same speed as does the cam. Were the outer end of the rotor segment any shorter than shown or were it possible to put the rotor in the wrong position on its shaft, then the segment might not be in contact with the terminal and the current would be required to jump an additional gap or else to fail to pass because of the added resistance. A majority of distributors in which the rotor is carried by the upper end of the breaker cam shaft are so built that it is impossible to replace them in any other position than the right one so that no trouble should be encountered from this cause.

At the bottom of Figure 51 is shown a breaker and distributor with the rotor carried on a gear driven

from the shaft that carries the breaker and running at one half the speed of the breaker shaft. This is the type generally used in magnetos and in some cases adopted for battery ignition systems. It is very essential that the distributor gear be correctly meshed with its pinion on the breaker shaft, otherwise the connection between the rotor and the cap terminals will be made at the wrong time and arcing will occur between these parts either during the time of advanced or retarded spark and in some cases a spark will be delivered to the plug of a cylinder which is not ready to fire.

This geared type of distributor is shown retarded at the right and fully advanced at the left. As retarded, the rotor is just making contact with the last part of one of the segments, which, in the type shown, are stationary and set into the distributor cap. When in the advanced position the rotor has not progressed as far and the spark takes place earlier in the piston's stroke. The rotor is accordingly making contact with the first part of the segment with which it comes in contact. The segment must then be made long enough so that the rotor is in contact with it from full retard to full advance.

In the type of mechanism shown at the bottom the gear which carries the distributor rotor and the pinion on the breaker shaft are usually marked on the teeth that should be in mesh so that correct replacement is rendered easy. In case the device is built for either right or left hand rotation (viewed from the driven end of the breaker shaft) the distributor gear is generally marked with two points for meshing, one being indicated by the letter L for

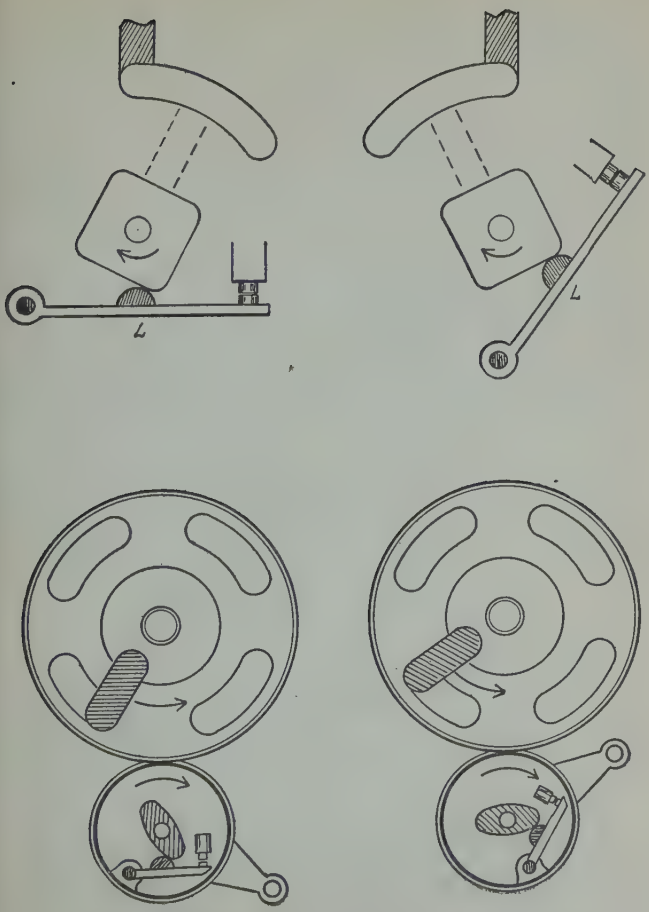


Figure 51.—Relation of Distributor Rotor to Segment. Top: Battery Type. Bottom: Magneto Type. Left: Retarded. Right: Advanced.

left hand rotation and the other by the letter R for right hand rotation.

Should the gears be improperly meshed so that an additional gap occurs in the distributor it will cause missing and irregular action with the engine running. The effect in the distributor will be to cause burning of the distributor cap segments because of the incorrect position of the rotor when the spark takes place. Should examination of such a distributor show burning and pitting of the segments at the end with which the rotor first comes in contact during its revolution, it indicates that the distributor gear is meshed too far back and it should be turned one or more teeth ahead with reference to the breaker shaft pinion, while if the burning is at the end of the segments at which the rotor leaves contact, the distributor gear should be set back one or more teeth. With the distributor gear set too far ahead the missing will occur with a retarded spark and with the gear set too far back the missing will be most noticed with an advanced spark.

ADVANCE AND RETARD

At first thought it would seem that the spark should pass through the inflammable mixture of fuel and air when the piston is at the top of its stroke and just ready to descend because it is at this time that the pressure of the burning mixture will do the most good in driving the engine. However, upon reflection it will be seen that this timing of the spark is not early enough to give the desired results except when the engine is being cranked or is running at the lowest possible speeds. Some of the factors affecting the timing of the spark and the time at which the

breaker contacts must separate were mentioned in Chapter One and it will be well to review these points in their practical applications.

Depending on the type of breaker and ignition mechanism used it will be necessary to cause the contacts to open more or less before the spark must pass in the cylinder. This early opening or advance is called for because of the electrical lag and because of a certain period of time which is required for the operation of the mechanical parts of the breaker, this latter being called mechanical lag. Electrical lag is in reality a magnetic lag or sluggishness with which the magnetizing force of the primary current in the coil produces its magnetizing effect on the iron core. This lag is accentuated by the tendency of the iron core to resist, and therefore, retard magnetization. In order to compensate for these two effects it is necessary that the breaker contacts open a certain time before the spark must pass and these conditions affect the ignition system whether the engine is running slowly or at a high rate of speed.

The most important element affecting the timing of the ignition, as it concerns the amount of advance given the breaker mechanism, is the time required for the flame to travel from the spark at the plug through the entire body of inflammable mixture in the combustion space and by causing this mixture to fully ignite to produce the maximum pressure on the piston head. The length of time required, measured in fractions of a second, for the flame to travel to the farthest points in the combustion space is very nearly constant regardless of the speed of the engine and of the piston's travel. On the other hand, the

piston speed, or the rate of travel with which the piston approaches the cylinder head, is of course in direct ratio to the speed of the engine.

It is true that the spread of the flame is affected by the degree of compression under which the gases are held when the spark passes and this compression pressure generally increases slightly with engine speed because at high speed the minute leaks from the combustion space do not allow as much of the gas to escape as at low speed. This condition of greater compression increases the speed of flame travel and causes the maximum pressure to occur quicker, thus tending in some degree to advance the effective timing of the ignition. It is also true that the proportions of fuel and air in the mixture affect the travel of the flame, but inasmuch as these conditions are not variable in any great degree without change in the carburetor action or adjustment, they may be neglected in determining the necessary spark advance. It is, of course, assumed that the fuel mixture is of the best possible proportioning and that the mixture is being properly heated.

The effect of increasing speed of the piston, together with practically constant speed of flame travel, then remains as the principal reason for providing spark advance for the breaker. Considering an engine with a six inch stroke turning at one hundred revolutions a minute (a practical cranking speed) the piston will travel through one hundred times its complete up and down movement, twelve hundred inches, in one minute which is a speed of twenty inches each second. If now we assume that the flame requires the one hundredth part of a second

to fully ignite all the gas it will be possible to arrive at any desired spark advance for this speed.

Referring to illustration A in Figure 52 we will assume the above mentioned conditions of flame travel and piston speed, and, for example, that full ig-

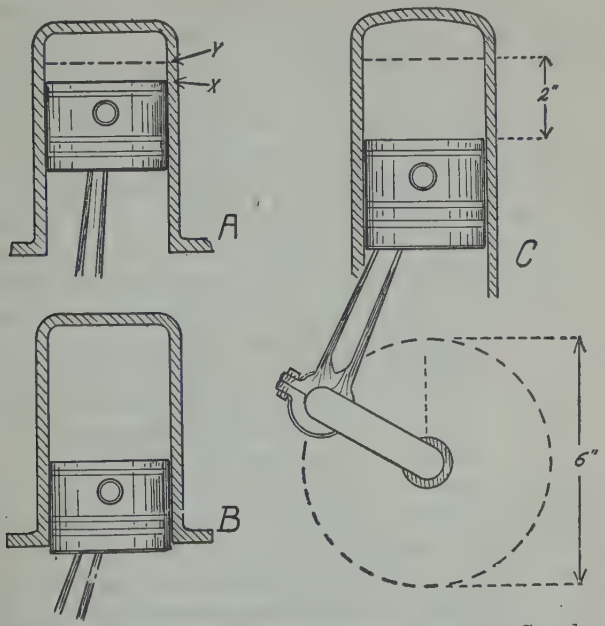


Figure 52.—Relation of Spark Advance to Piston Speed and Travel.

nition of the gases is wanted with the piston at top dead center, which position is indicated by line Y. The piston is supposed to be moving at the rate of twenty inches each second and in the one hundredth part of a second required for flame travel, the piston

will move one one-hundredth of twenty inches or 2/10th of an inch. Referring to the illustration, the line X (the top of the piston) should then be 2/10ths of an inch below top center when the spark passes because with this advance of the spark the flame will have fully ignited the gases just as the piston reaches the extreme top of its stroke. This advance of 2/10th of an inch is an advance equivalent to 1/30th of the entire stroke or about 20°, and would be excessive for cranking in actual practice.

Then referring to B in the same figure, assume that the time for complete ignition after the passage of the spark is still the same, 1/100th of a second, but assume the engine crankshaft speed to be 2000 revolutions a minute. In 2000 revolutions the piston will travel up and down (six inches each way) 2000 times in a minute and will travel 24,000 inches a minute or 400 inches a second. In order to still allow the flame 1/100th of a second to fully ignite the gas it would be necessary to cause the spark to take place four inches (or two-thirds of a stroke) before top center because the piston will travel this four inches in 1/100 of a second and upon arrival at top center find the gases fully ignited. This speed would be too great for ordinary use in an engine having a six inch stroke, but is used simply to show the great advance required in spark timing to make up for the increase in piston speed.

As a practical illustration of the advance required as measured in degrees of crankshaft or flywheel travel, consider the case shown at C in Figure 52. The flame travel is here assumed to require 1/120th of a second and the engine to be turning at a rate

of 1200 revolutions a minute. The piston speed will then be 14,400 inches a minute or 240 inches a second. Traveling at this rate the piston will move two inches in 1/120th of a second, or the distance between the top of the piston head as shown and the dotted line indicating top center. With a six inch stroke this two inch advance will correspond to a crankshaft travel of nearly 60° as shown and this amount of advance will be required for the opening of the breaker contacts before the piston reaches top center. In actual practice, modern ignition

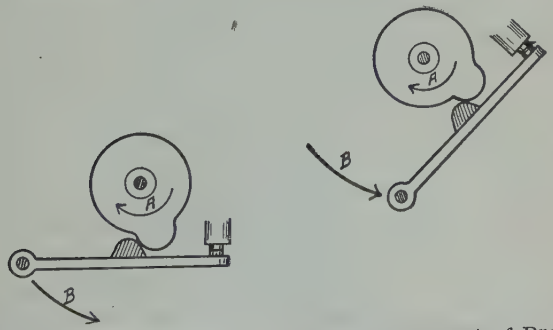


Figure 53.—Spark Advance Caused by Movement of Breaker Arm. Left: Retarded. Right: Advanced.

devices are constructed to provide a range of from 30° to 60°, and in rare cases even greater advance than this.

The spark advance may be secured through movement of the breaker housing and base plate together with the contact arm and contacts, or else by moving the cam in relation to the shaft by means of which the breaker is driven. With the method of moving the housing and contacts, the advance is se-

cured by turning the housing around the shaft in a direction the opposite of that in which the shaft turns. The effect of such movement of the contact carrying member is shown in Figure 53 by illustrating a cam with but a single lobe rotating in a clockwise or right hand direction. The direction of rotation of the cam and its shaft is shown by the arrow A and the direction in which the breaker arm and contacts should move for advance is shown by arrow B. It will be seen that movement of the arm and contacts in the direction of B would cause the bumper to be struck by the cam and the contacts to be separated before the cam had reached the position shown, or, in other words, earlier in the operation of the engine and in the stroke of the piston. The retarded positions are shown at the left of the illustration and the advanced positions at the right. In the advanced positions it will be seen that the lobe on the cam will strike the bumper on the arm some time before it would do so when retarded and by the amount of this movement of the breaker housing and arm with the contacts, the degree of advance is determined and suited to the speed and running conditions of the engine.

In some types of construction the breaker arm and contacts remain stationary and the cam itself is moved relative to its shaft. One method of securing this result is shown in Figure 54 which shows one form of hand advance used with Delco ignition devices. The shaft which carries the breaker cam is in the form of a tube and a helical slot is cut through the wall of this hollow driving shaft. A smaller shaft is carried inside of this hollow tube and this

smaller shaft is driven from the engine. A vertical slot is cut down through the smaller shaft and a pin passes through both the straight slot in the small shaft and the helical slot in the cam shaft. This pin is held by a collar which is adapted to slide up and

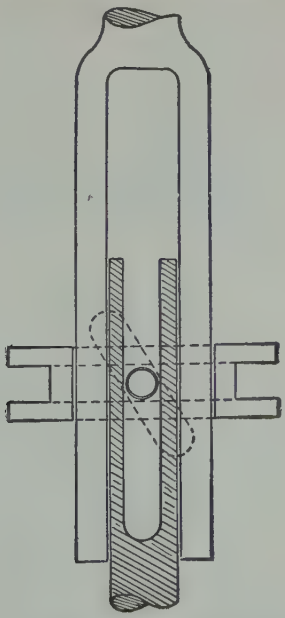


Figure 54.—Helical Slot Advance Mechanism (Delco).

down on the outside of the hollow shaft. If the collar which holds the pin be moved up or down, the movement of the pin along the helical slot will cause the tubular shaft with the breaker cam to turn with reference to the smaller solid shaft and this turning will either be in the direction of rotation

or in the opposite direction, depending on whether the collar and pin are moved one way or the other.

In such a mechanism it is obvious that if the cam and its shaft are moved in the same direction that they normally rotate, the ignition timing will be advanced because the lobes of the cam will then act on the breaker arm earlier in the piston stroke and crankshaft revolution than they would otherwise. On the other hand, the ignition will be retarded by moving the cam in the direction opposite to that of rotation because this practically turns the cam a part of a revolution backward so that it acts on the breaker later than it otherwise would.

AUTOMATIC SPARK ADVANCE

It has been shown that the principal factor governing the degree of spark advance is the speed of the engine and it is because of this fact that a number of automatic devices have been adopted which allow this speed of the engine to effect a corresponding advance in the time at which the breaker contacts open. All of these mechanisms make use of the centrifugal force generated by weights which are driven by the engine. The force thus generated is opposed by the tension of various forms of springs and the balance between the spring tension and the power of the revolving weights determines the spark advance.

Automatic spark advance has the advantage of causing the mixture to be ignited at the time that is theoretically correct without attention by the operator and in the case of inexperienced or careless

users this is an undoubted benefit to the engine. Automatic advance avoids the penalties of a too late spark which include waste of fuel, loss of power, overheating of the engine and burning of the lubricating oil and the valves. It also avoids the dangers from a spark that is timed too early, these including such things as damage to the electric starting motor

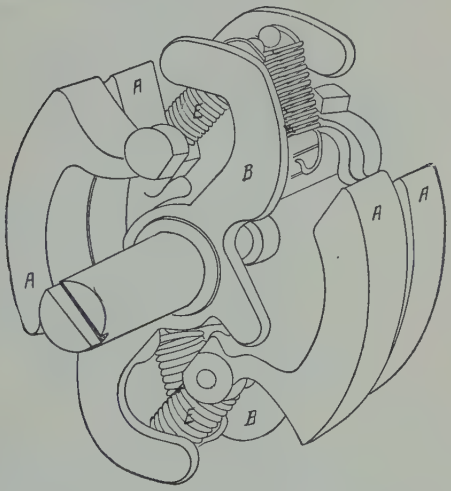


Figure 55.—Governor for Automatic Advance.

and battery or to the person cranking the engine by hand, damage to the bearings and shafts because of the strains which are indicated by knocking and again, loss of power and consequent waste of fuel. Among the disadvantages of automatic means of spark advance are the added mechanical complication which comes with any additions to the power

plant and the unreliability and trouble found with some forms of advance devices.

While all forms of automatic advance are capable of providing an ample range of advance and retard for the proper operation of the engine, it is customary to fit the ignition devices having such automatic advance with a manual or hand operated advance and retard lever also. This manual advance may be used in the ordinary way by the operator or it may be set in the position found best for the engine operation under any given conditions or on any particular day, then allowed to remain there until weather, temperature or fuel conditions change and make a new position of the manual advance desirable.

Automatic advance uses governors with pivoted weights, fly-balls, or unbalanced rings driven by the engine drive shaft. The main drive shaft is separate from the breaker cam shaft, with the main shaft driving the governor and the governor in turn driving the breaker shaft. Movement of the governor weights turns the breaker shaft and its cam slightly ahead of the main shaft to give the advance.

Figure 55 shows the construction of an automatic advance that has been used on a great many Atwater Kent installations. This mechanism is carried in a cylindrical housing directly underneath the breaker and distributor and on a vertical shaft which is driven at one half the speed of the engine crank shaft. This governor consists of two pairs of weights A, each pair being pivoted together at their centers, and in addition to the weights the two double arm brackets B. When the drive shaft is revolved by the engine, the weights tend to fly away from the center and in doing so they cause the arms B to

revolve a part of a turn with reference to the shaft D. In order that the weights will not move away from the center too easily and thus give too great an advance at low engine speeds the springs E are so attached to their brackets and the weights that they oppose the outward movement of the weights. Each weight is in effect a bell crank lever with one point

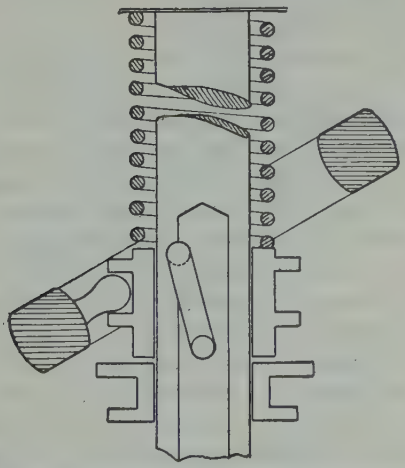


Figure 56.—Ring Type of Automatic Spark Advance Governor (Delco).

of connection pivoted on the arm and the other point of connection pivoted to the weight. The four weights work in the same direction at the same time against their four respective springs.

In Figure 56 is shown a section through the first type of automatic advance governor used with Delco equipment. This governor is of the ring weight type and is used in connection with the advance method

which has already been described and illustrated in Figure 54. In the case of the automatic governor the ring by which the pin is carried is actuated by the force of the revolving ring in place of by manual means. It will be seen from the illustration that the ring is supported by a pivot passing from side to side through its width and that on one side of the ring and inside the circle is an extension or knob which engages a slot cut around the ring and which operates the advance pin in the slots of the shafts. The ring weight is normally held in the slanting position as shown, by the tension of a coiled spring around the shafts and above the actuating ring. With increase of engine speed the ring weight tends to straighten out and revolve with its axis in line with the center line of the revolving shafts, that is, the body of the ring weight attempts to get as far away from the shaft as possible. In thus moving against the tension of the spring the lug on the ring weight lifts the collar and causes the pin to move the breaker shaft relative to the engine driving shaft.

The type of automatic advance used with later types of Delco equipment is shown in Figure 57. Above is shown a vertical section through the device and below is the top view of one of the weights with its method of engaging the breaker cam shaft. Three centrifugal weights are carried around the breaker shaft, and on the shaft which carries the breaker cam are three extensions which are acted upon by hooked shaped members on the ends of the weights and near the pivots by means of which the weights are supported and driven. As the speed of the engine and of the driving shaft increase, the weights tend to

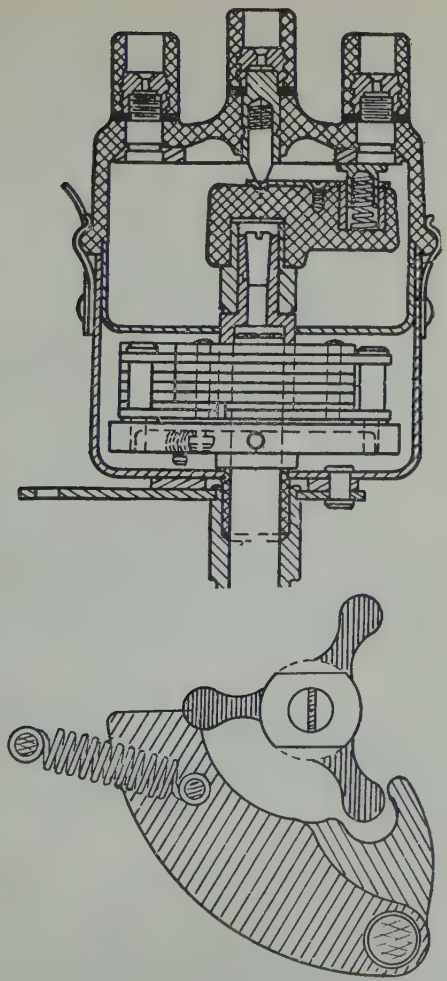


Figure 57.—Delco Automatic Advance. Top—Section Through Unit. Bottom—Weights and Arms.

fly out and this tendency is resisted by the coiled springs, one of which is shown attached to its weight in illustration, Figure 57. The movement of the weight causes the hook to pull the three-armed spider farther around in the same direction that the shaft rotates and the ignition timing is thereby advanced.

REVIEW OF CHAPTER IV

IGNITION TIMING

The breaker cam, with battery ignition, **runs at camshaft speed.** With one set of contacts, there are as many **lobes** on the cam as there are cylinders to be fired.

Timing a battery ignition breaker is done as follows:

(1) The spark control is placed in its fully retarded position.

(2) The piston of number 1 cylinder is brought to top dead center between the compression and firing strokes. This is one full turn from the point at which the exhaust valve has just closed and the inlet just started to open.

(3) The breaker cam should be moved in the direction it runs until the contacts just start to separate, and locked at that point.

(4) Crank the engine by hand while watching the piston travel in number 1 cylinder. This cranking takes up the play in the breaker drive and allows a slight delay or retard in the instant at which the contacts separate. They should now separate at top center or immediately after top center if the timing is correct.

Firing orders in most common use are as follows:

4-cylinder engine: 1-3-4-2 or 1-2-4-3.

6-cylinder engine: 1-5-3-6-2-4 or 1-4-2-6-3-5.

8-cylinder V-type: 1L-2R-3L-1R-4L-3R-2L-4R.

8-cylinder straight: 1-3-2-5-8-6-7-4 or 1-5-3-7-4-8-2-6.

12-cylinder V-type: 1L-3R-4L-5R-2L-1R-6L-4R-3L-2R-5L-6R.

Firing orders are determined by watching the opening and closing of either the exhaust valves or the inlet valves, starting with the opening of the valve for number 1 cylinder, then cranking slowly to note the next valve of the same kind that opens.

Distributor wiring is done as follows:

(1) The firing order of the engine is determined and a note made of it.

(2) The engine is cranked until the piston for number 1 cylinder is at top center between the compression and exhaust strokes, the firing point.

(3) The distributor cap is removed and note made of the point or spark plug wire terminal to which the outer end of the rotor is pointing.

(4) A wire is connected between the distributor cap terminal to which the rotor points and the spark plug in number 1 cylinder.

(5) A wire is then connected between the next distributor terminal with which the rotor makes a circuit and the spark plug for the second cylinder to fire, according to the firing order of the engine.

(6) The remaining distributor terminals are connected with the spark plugs in the order in which the rotor completes the circuits and in the order of firing.

The **rotor setting** should be such that with the spark control fully retarded, connection is being made at the end of the long segment (on the rotor or in the cap) away from which the moving parts are traveling with the distributor turning in its running direction. With the spark control fully advanced, the connection should be made at the end of the segment first approached as the distributor rotor turns. With the control midway between retard and advance, connection should be made approximately at the center of the segment.

Spark advance is required according to the speed at which the engine is running, varying from no advance to 60 degrees on the flywheel.

Greater advance is secured by moving the breaker cam in the same direction it rotates, or by moving the housing or contacts in a direction opposite to that of cam rotation.

Greater retard is secured by moving the cam against rotation, or the contacts with rotation.

Automatic advance mechanisms allow a governor to move the breaker cam with rotation in relation to the driving shaft as the engine speed increases.

Manual control is usually used in connection with automatic advance.

CHAPTER V

BATTERY IGNITION SYSTEMS

ATWATER KENT TYPES CC AND CA

The breaker construction for CC and CA type ignition is shown in Figure 58. The CC type has manual advance, while the CA type uses the automatic advance shown in the lower right hand corner of Figure 58. Otherwise the two types are similar. With the breaker shown at the top of Figure 58, the contact gap should be set between .006″ and .008″. With the breaker shown at the bottom, the gap should be set at .015″. The adjustment on the upper style of breaker is made by loosening the screw in the holder for the stationary contact and sliding the holder forward or back. The lower style of breaker, a later construction, uses a conventional screw adjustment. The condenser is mounted in the breaker, being fastened as shown in Figure 59. The distributor is of the jump spark type, shown in Figure 60 at the bottom.

The type N coil is shown at the upper right in Figure 60. A separate condenser may sometimes be used with this type of coil, the condenser being clamped around the coil housing.

The wiring for this equipment with type C coil is shown at the top of Figure 60. This coil is cylindrical with the resistance unit carried underneath a ventilating cover at the top. The primary wire for

the breaker is brought out through the side of the case without a terminal. Reversing switches have been used with some of these systems.

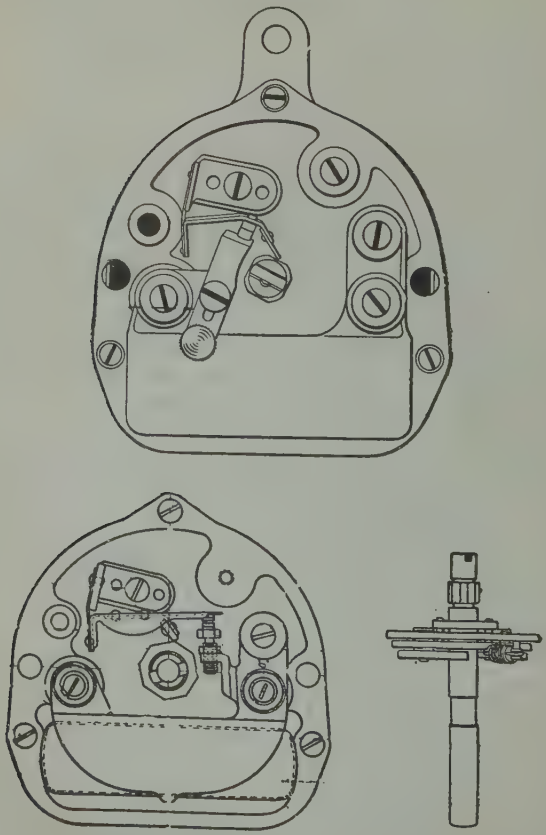


Figure 58.—Atwater Kent Breakers.

ATWATER KENT OPEN CIRCUIT SYSTEM

Earlier types of Atwater Kent equipment used the open circuit breaker whose action is shown in Figure 61. The contacts are normally separated, being held

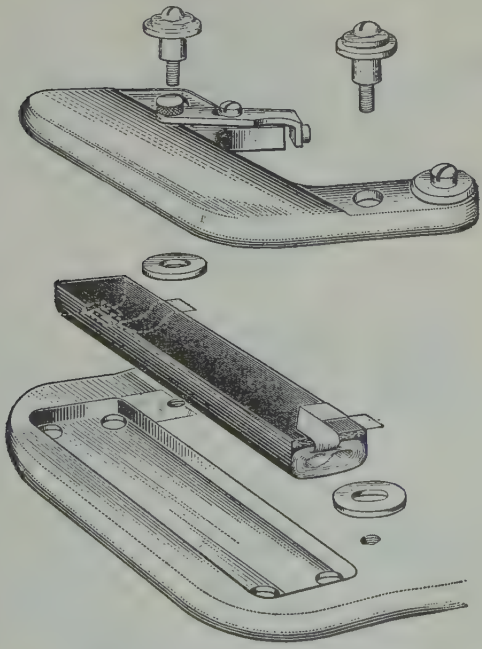


Figure 59.—Atwater Kent Condenser Mounting.

on the adjustable contact screw and the contact spring. As the notched shaft rotates in the direction of the arrow it catches the hooked end of the lifter and draws the lifter along with it, stretching the lifter

spring. With continued rotation, the high part of the shaft between notches pushes the hook on the lifter

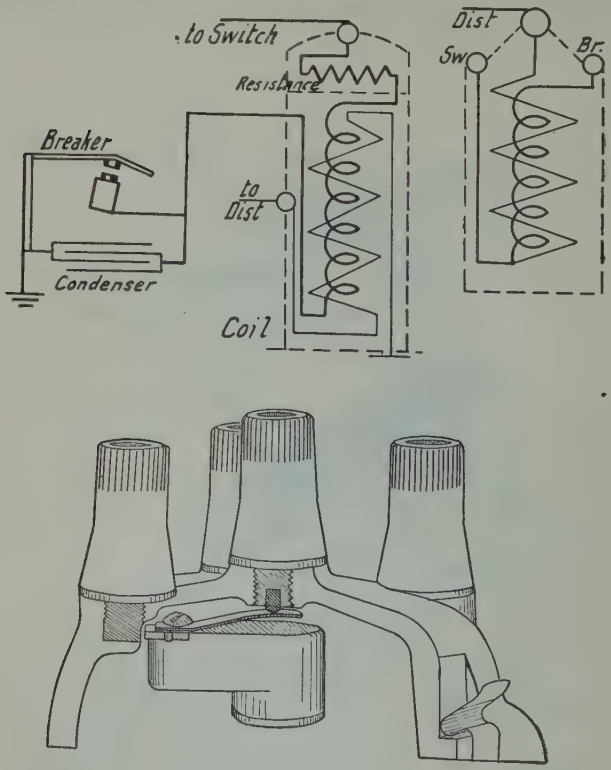


Figure 60—Atwater Kent Coils and Distributor.

out of the notch and the spring snaps it back. In passing back over the high part of the shaft, the lifter strikes against the latch and the latch throws

the contacts together for an instant. The duration of the contact, during which primary current flows through the coil, is independent of the engine speed, being just the same at all speeds. The gap between

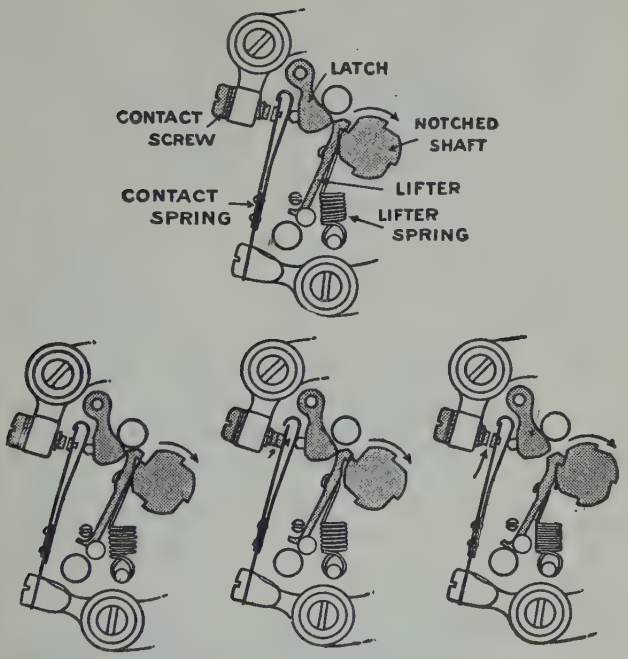


Figure 61.—Atwater Kent Open-Circuit Breaker. Left—Contacts Open. Center—Contacts Closed. Right—Contact Broken.

the contacts should be set at .010″ to .012″. A hotter spark is secured with the smaller gap. The adjustment is made by removing or replacing thin washers underneath the head of the contact screw.

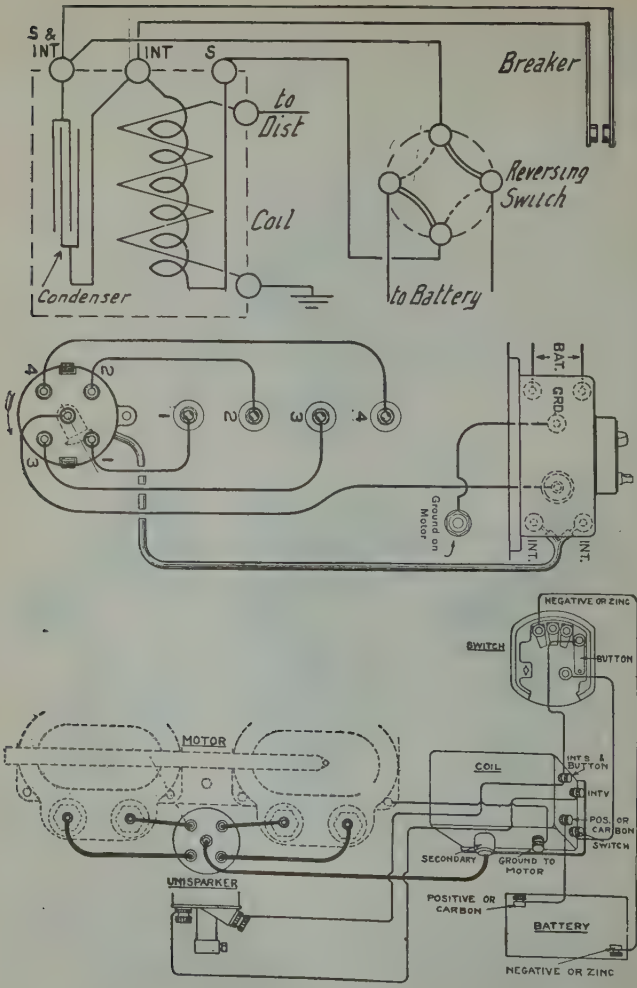


Figure 62.—Atwater Kent Open Circuit Systems.

The short time during which the contacts are closed with this system requires a coil especially wound to give a spark with very little primary current. The

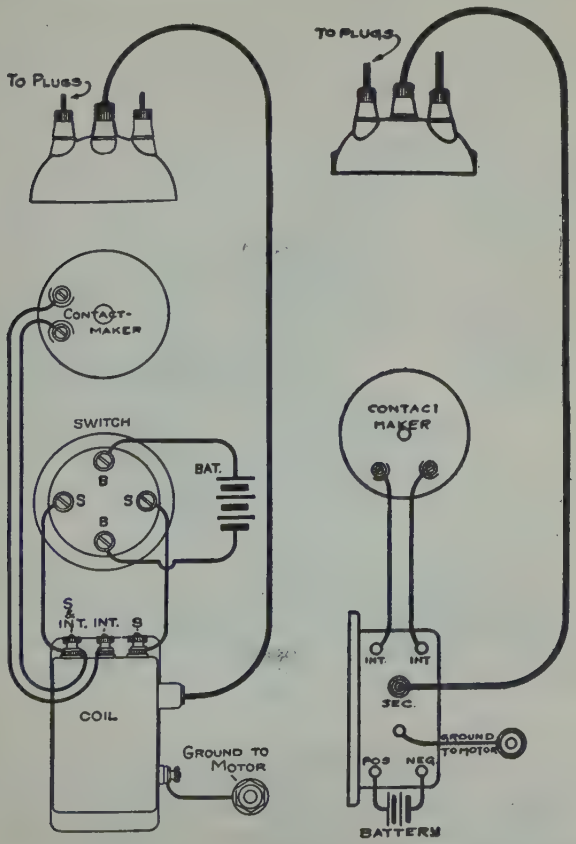


Figure 63.—Wiring of Atwater Kent Open Circuit Systems with Separate Reversing Switch and with Switch on Coil Box.

wiring for this system with a reversing switch is shown at the top of Figure 62. External wiring for various arrangements of open circuit breaker systems is shown at the bottom of Figure 62 and in Figure 63.

These systems of types C, F, and H have hand advance only, while types K, K2 and K3 use the automatic advance. With automatic advance a manual control is also fitted so that the breaker may be moved for about a quarter of an inch. With the manual advance types, timing is done by slowly turning the breaker shaft in the direction it runs until a click is

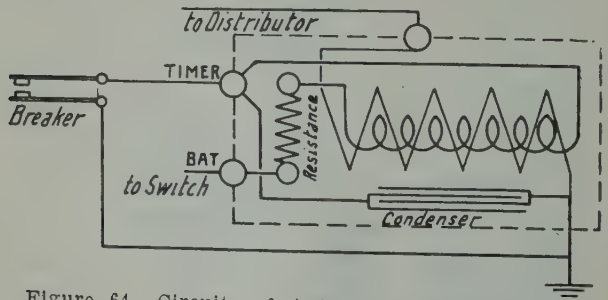


Figure 64.—Circuits of Auto-Lite Ignition System.

heard, this indicating operation of the contacts. With the automatic advance types, the breaker housing is turned in a direction opposite to the rotation of the shaft until the click is heard.

AUTO-LITE

The wiring for Auto-Lite battery ignition is shown in Figure 64. The resistance unit is mounted on a flat mica-covered strip carried on one end of the coil. The condenser is in the coil. Both sides of the breaker are insulated, but one side is grounded through a con-

nection on the coil base to which also attach the condenser and one end of the secondary winding. Contact gap setting is .020″ to .022″.

BOSCH

The wiring for Bosch battery ignition systems is shown in Figure 65. The TC-4 and TC-20 coils are

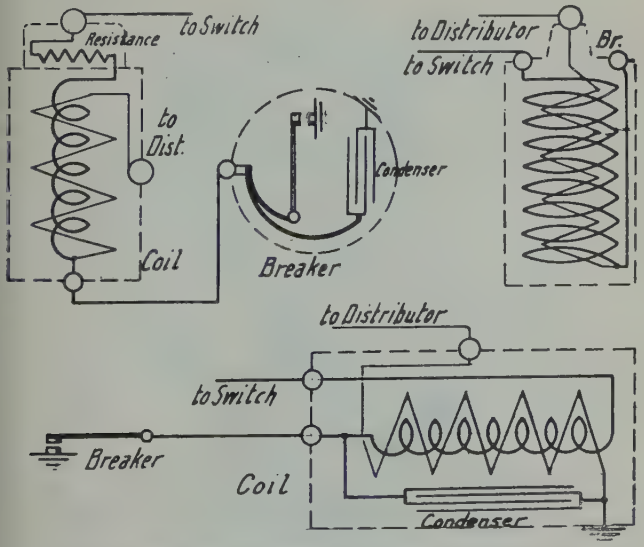


Figure 65.—Bosch and Gray & Davis Coil Circuits.

shown at the upper left hand side and the TC-30 and TC-40 coils at the right.

The left hand type of coil uses a resistance unit mounted on top of the coil. Changing the resistance allows the same coil to be used with either 6-volt or 12-volt systems. The coil at the right is used without

a resistance and is furnished in either 6-volt or 12-volt types. Its construction differs from the usual practice in having the primary winding around the outside of the secondary winding. The top terminal is

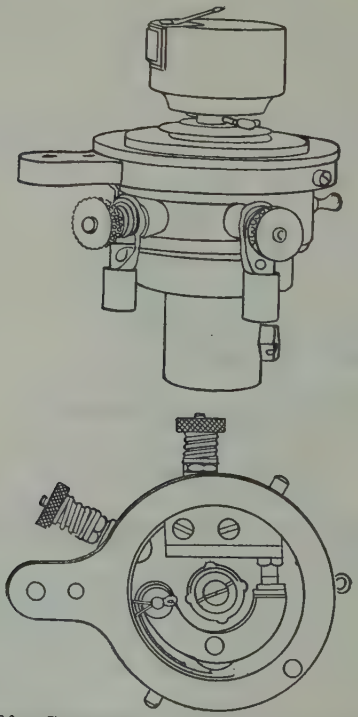


Figure 66.—Connecticut Breaker and Distributor.

the high tension connection to the distributor and the side terminals are connected to the switch and the breaker. A Gray & Davis type of coil is shown at the bottom of Figure 65.

The Bosch breaker is of the grounded construction and carries a condenser inside its housing. Type T is built for automatic advance and type TM for manual advance. The automatic advance mechanism uses a tilting ring weight that moves the breaker cam shaft through a pin and spiral slot as the ring straightens out. The spring is of spiral type fastened to the hub

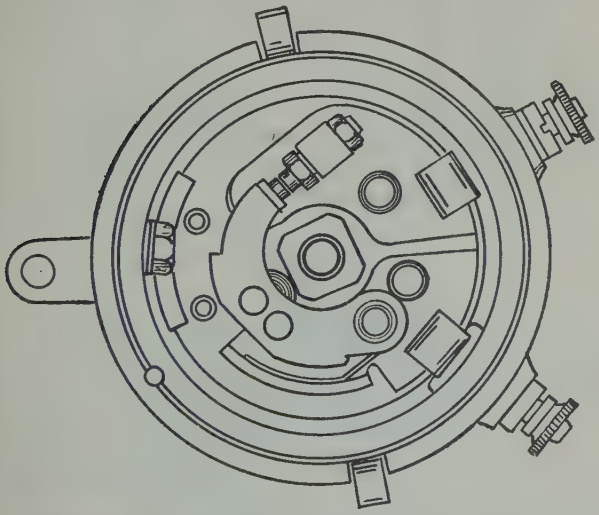


Figure 67.—Connecticut Breaker with Stationary Outside Terminals.

of the tilting ring. The construction is somewhat similar to that shown in Figure 56.

CONNECTICUT

Constructions of Connecticut breakers and a distributor are shown in Figures 66, 67 and 68. Both contacts are insulated. Advance and retard are se-

cured by moving the base plate carrying the arm and contact, the wires remaining stationary and maintaining connection with the contacts through small springs in the housing. Older equipments used a wipe contact distributor, shown in Figure 66, while later ones use the jump spark type of Figure 68.

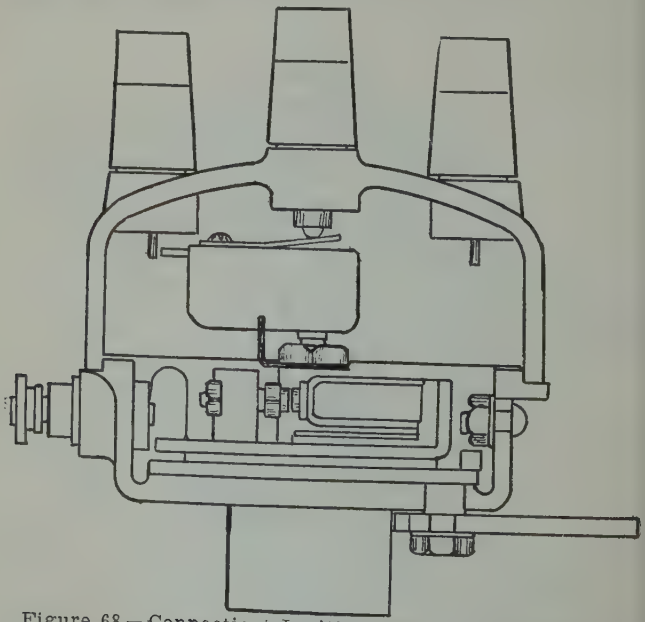


Figure 68.—Connecticut Ignition Head with Jump Spark Distributor.

The wiring of Connecticut coils is shown in Figure 69. With the GA, GO, and M types two of the terminals are connected with the breaker, the condenser being carried in the coil or on the base and thus connected between the breaker contacts.

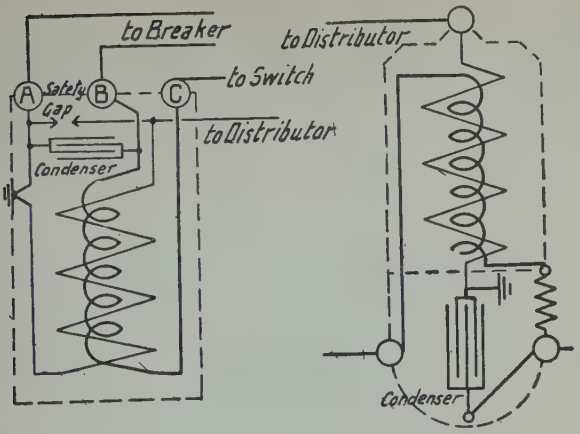


Figure 69.—Connecticut Coils. Left—GA, GO and M Types. Right—Y Types.

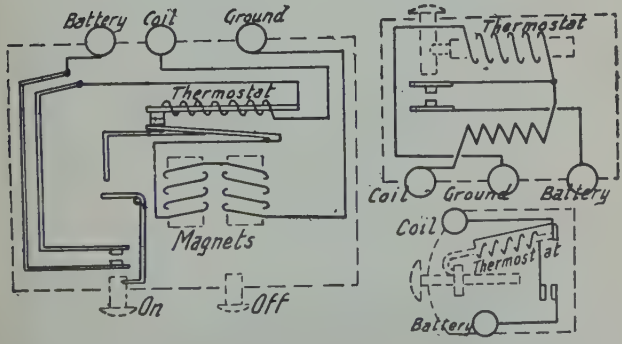


Figure 70.—Connecticut Automatic Switches. Left—Type H. Right—Types K and M.

Many Connecticut installations include an automatic ignition switch that opens the circuit should the switch remain closed with the engine idle and the breaker contacts together for any length of time. This avoids the necessity for using a resistance unit and protects the coil and breaker contacts from overheating.

Three types of these switches are shown in Figure 70. In the type H, bending of the thermostat blade when heated closes the thermostat contacts and allows current to flow through the magnet coils. The magnet armature is attracted and strikes a latch which releases the switch button. Primary ignition current flows around the thermostat blade and if this current continues at high amperage it makes the blade hot enough to bend. With the engine running, the current through the primary circuit is too low to heat the thermostat blade. In type K and M, which are later constructions, the electromagnet is done away with, the switch button being released when the thermostat blade moves out of a notch in type K, or off a projection on type M on the body of the button. The button is then thrown out by a spring. The type H switch is sometimes found built into a coil.

DELCO

The first Delco breakers were of the open circuit type, shown in Figure 71. The contacts are normally held open by the spring and are closed by the cam. The form at the bottom is used for battery ("magneto") and dry cell sources of current, one set of contacts being provided for each source. At the top of Figure 72 is shown the breaker used during 1916 and 1917 and at the bottom is a type used from 1918 to

1922. Both of these types are of conventional form with the breaker arm grounded. Figure 73 shows types of breakers in which are mounted condensers,

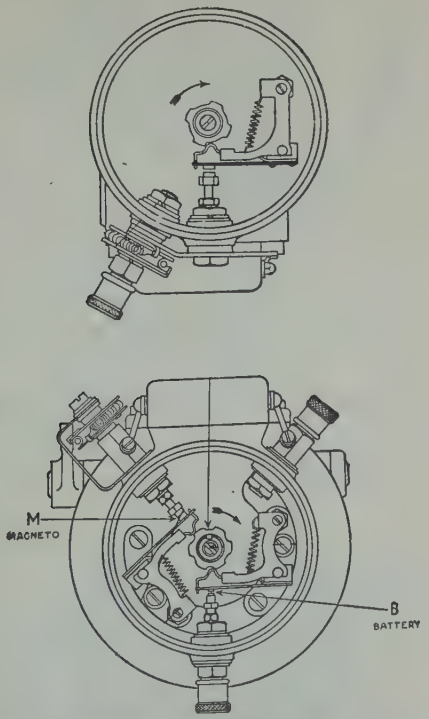


Figure 71.—Delco Open-Circuit Types of Breaker. Breaker for Two Separate Batteries at Bottom.

these being used from 1918 to the present in systems having no condenser in the coil. The one at the top has the flat condenser, while the lower types have

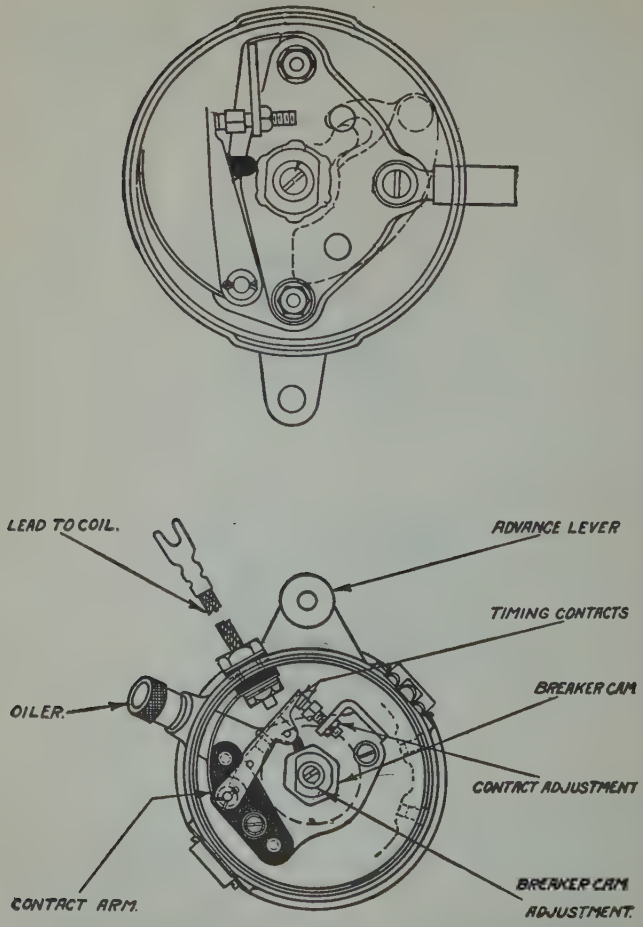


Figure 72.—Delco Closed Circuit Types of Breakers.

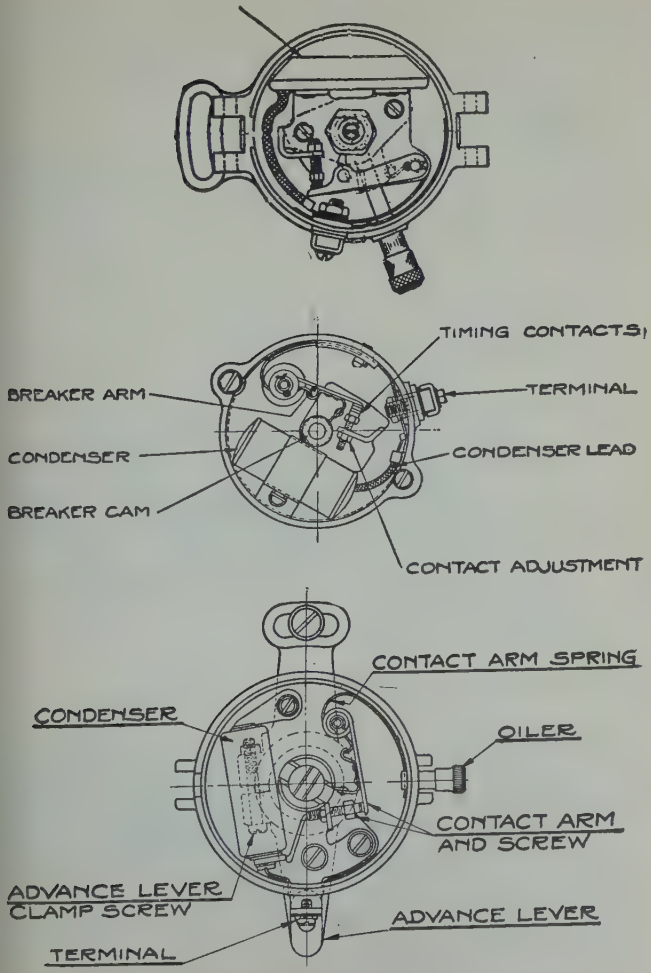


Figure 73.—Delco Breakers with Condensers.

the round condenser. Four and six-cylinder breakers open .020″ to .027″. Both wipe contact and jump spark distributors are used with these breakers. The construction of the Delco automatic advance mechanism is shown in Figure 57.

The first Delco coil construction, used until 1915, is shown in Figure 74. The breaker used with this type of coil has a condenser mounted on the outside of its case and grounds through the ignition resistance, also carried on the breaker.

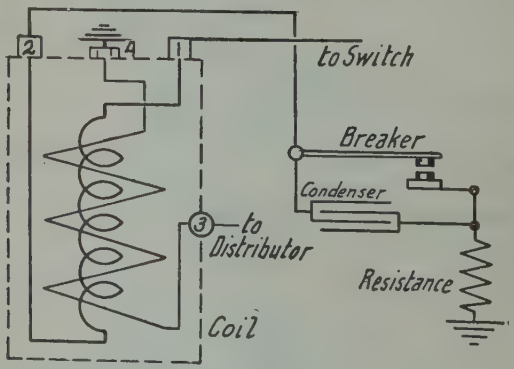


Figure 74.—Early Type of Delco Coil.

A coil containing a condenser and carrying the resistance is shown at the top of Figure 75, also at the top of Figure 37. The type at the top of Figure 75 was used from 1916 to 1920 and the type at the top of Figure 37 was used during 1916. These coils are used with breakers shown in Figure 72.

Coils without a condenser, but with the resistance mounted on them are shown at the center and bottom of Figure 75. These coils are used with the breakers

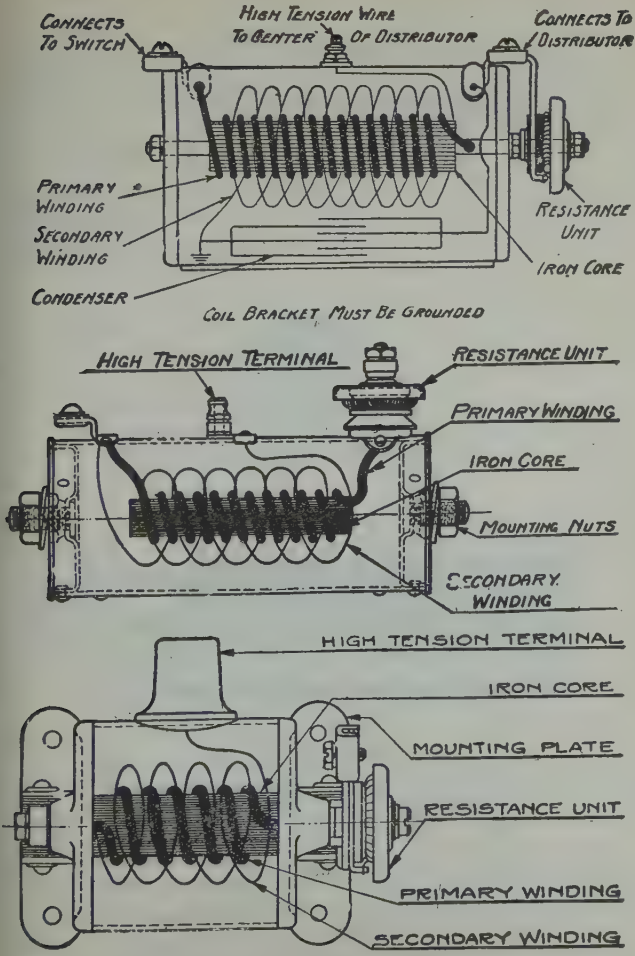


Figure 75.—Delco Coils with Resistance Units.

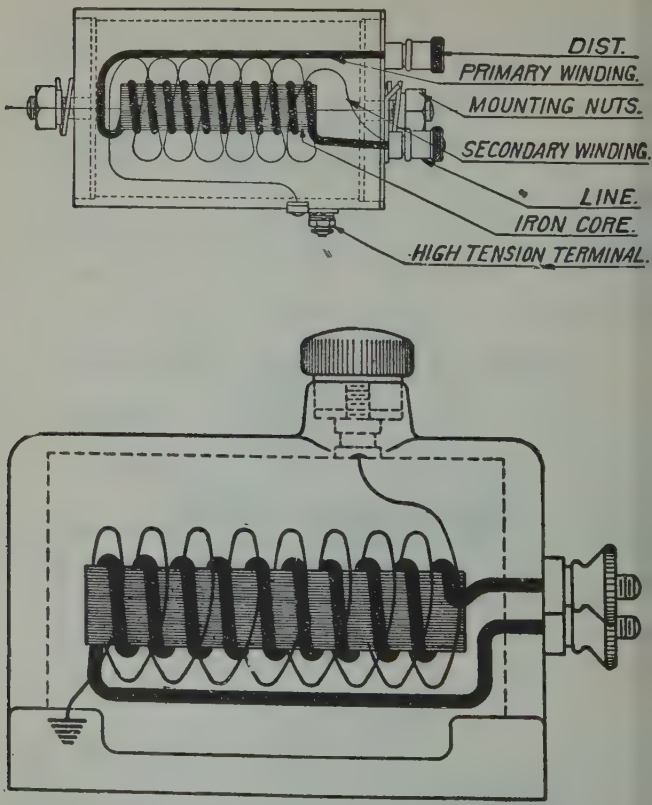


Figure 76.—Delco Coils without Resistances or Condensers.

shown in Figure 73, from 1918 to the present. Two types of coils without either condensers or resistances are shown in Figure 76, these being two of the late types now in use.

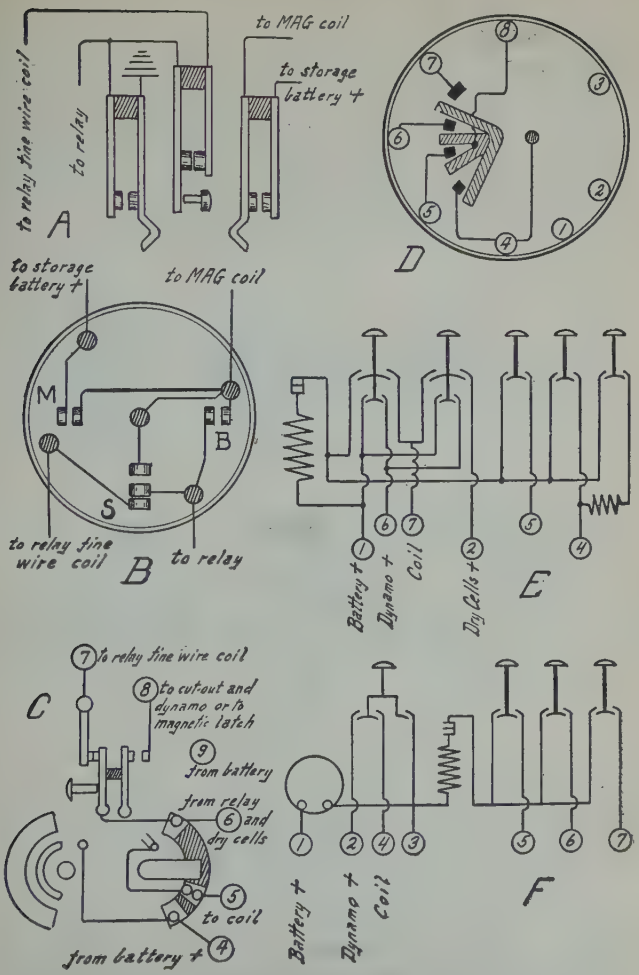


Figure 77.—Delco Ignition Switches and Combination Ignition and Lighting Switches.

Condensers for the earlier Delco systems are mounted outside the breaker housing, for later systems they are carried in the coils as shown by the drawings, and for the latest systems the condensers are carried inside the breaker housing. Resistance units in some of the earliest systems were carried separately on the dash and in later equipments they

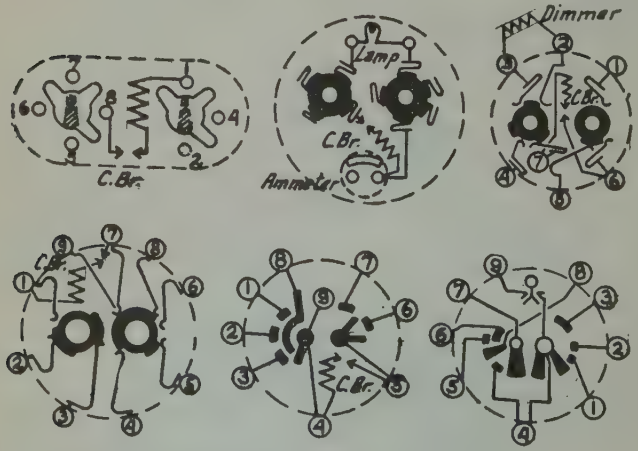


Figure 78.—Delco Combination Switches.

have been either on the coils or on the breakers. The resistances carried on the breakers may be either on the insulated or the grounded side of the breaker.

Several of the older types of Delco ignition switches, also some of the combination ignition and lighting switches, are shown in Figure 77. The switch at A was used until 1914 with dry cell and storage battery ignition. The center button is for starting on the

ignition relay. The type at B, used in 1913, has four press buttons and is used for either dry cell or storage battery ignition. The combination switch at C was used in 1914 and 1915. At D is a later type of rotary combination switch. At E is the combination switch with five buttons as used in 1915. This switch provides a manual cut-out on the ignition buttons, one of which is for dry cell and the other for storage battery ignition. A four-button type of switch oper-

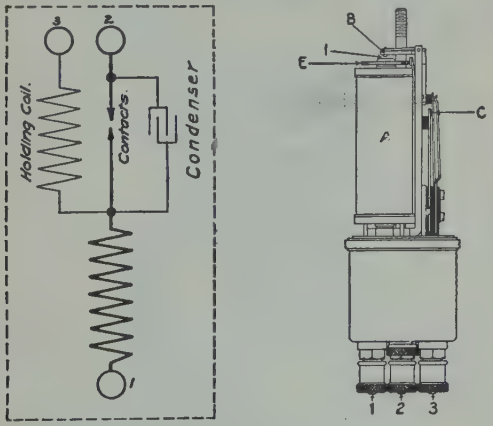


Figure 79.—Delco Ignition Relay.

ating in a similar manner is shown at F, this switch being used from 1916 to 1918.

Later types of Delco switches are of the combination type, a number of styles used from 1916 to the present being shown in Figure 78.

The Delco ignition relay, used from 1910 to 1914, is shown in Figure 79. Primary current flows around magnet A, attracting armature B and opening con-

tacts C, which breaks the primary current through the coil and causes a spark. The contacts close again with

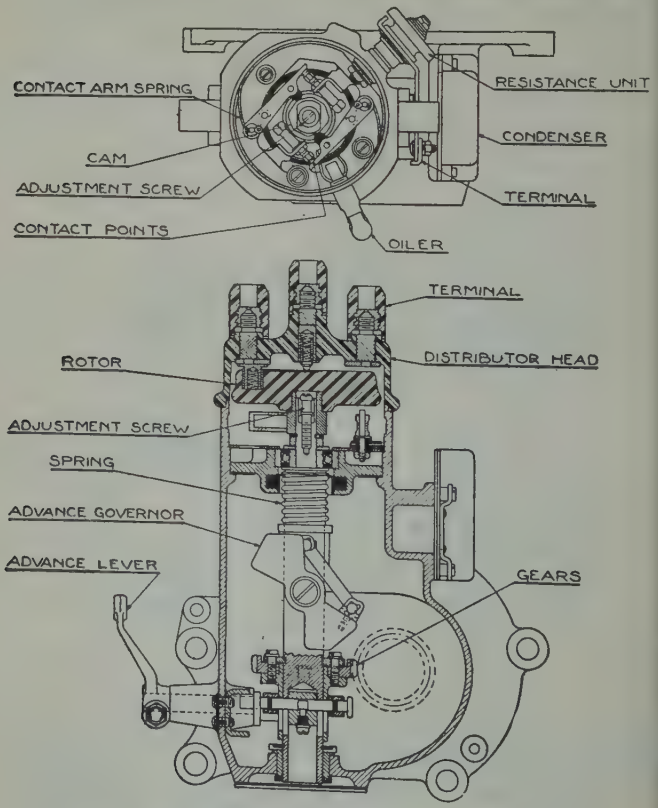


Figure 80.—Delco Eight-Cylinder Ignition Head.

the current stopped, and the action goes on, causing a spark at each vibration. If the switch is placed to let current through the holding coil, it keeps the

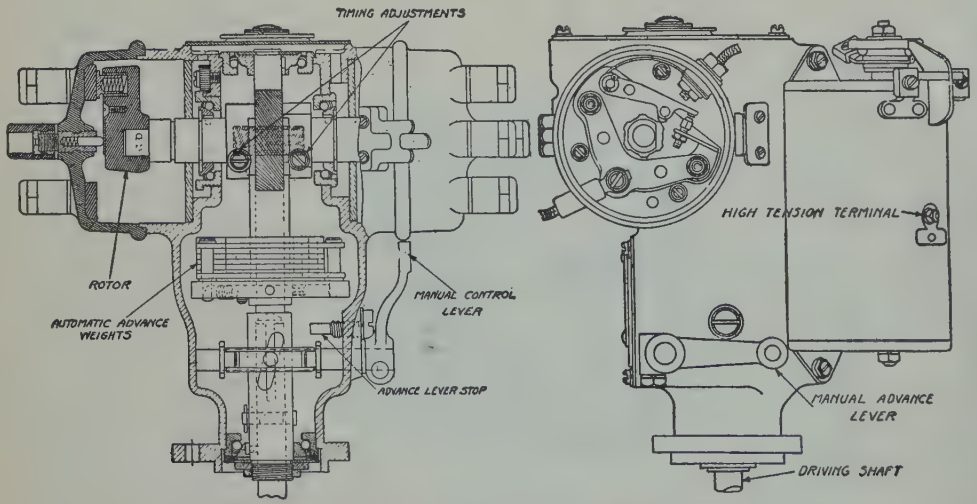


Figure 81.—Delco Twelve-Cylinder Ignition Head.

contacts apart after they once separate and only a single spark is produced for each operation of the breaker contacts. The screw E adjusts the gap I to regulate the operation of the relay.

An eight-cylinder ignition head having two sets of contacts is shown in Figure 80, and a twelve-cylinder type with two separate breakers is shown in Figure 81. A double ignition head, firing two plugs in

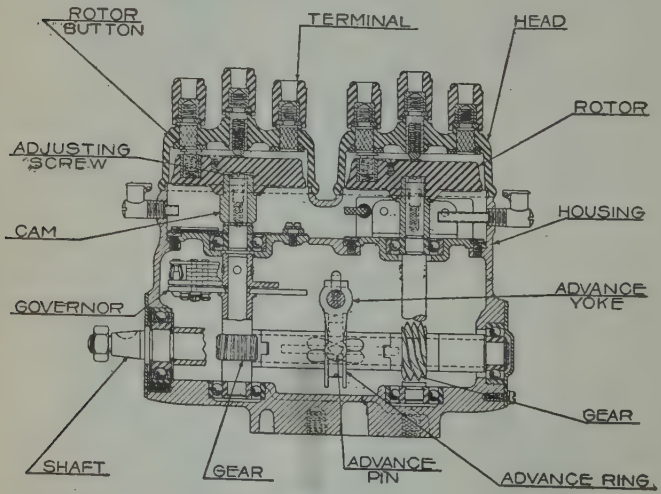


Figure 82.—Delco Double Ignition Head for Six Cylinders.

each cylinder for two-spark ignition, is shown in Figure 82.

KINGSTON

Wiring for the Kingston battery system of ignition is shown in Figure 83. The coil carries a resistance unit on top and connected between the switch ter-

minal and the primary winding. The condenser is carried inside the coil and connected between the two contacts that connect with the breaker. With a grounded breaker, in place of the insulated type shown, one of the coil terminals is also grounded to complete the condenser circuit. Some of these equipments use a reversing type of switch from which wires run to the regular switch terminal on the coil and also to the terminal that carries one of the breaker wires as well.

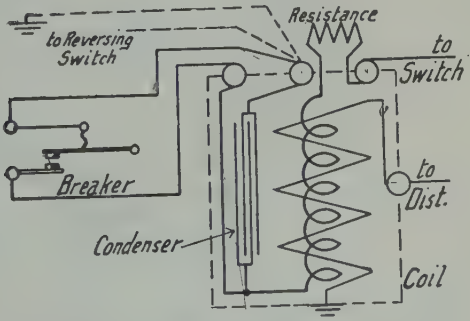


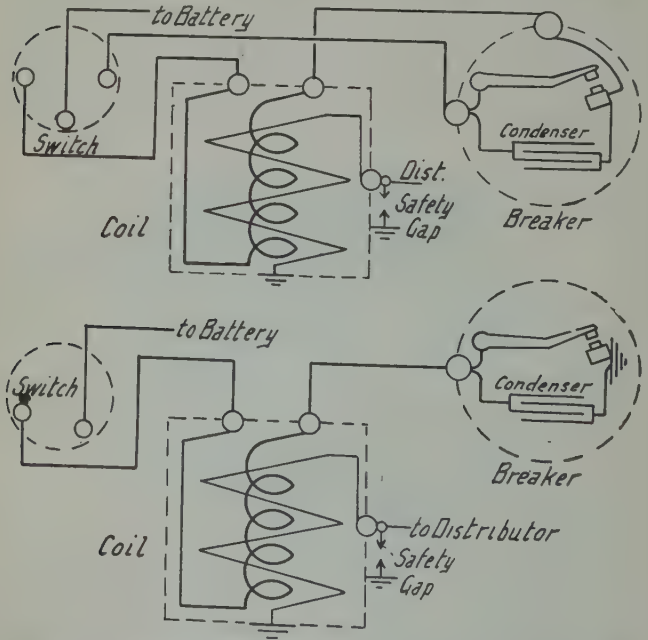
Figure 83.—Kingston Coil and Connections.

The breaker has both contacts insulated and carried on a rotating plate in the housing. A small coiled spring under compression is used near the contact end of the breaker arm. The contact gap should be .018″. The distributor is of the jump spark type.

NORTH EAST

The circuits of a North East ignition system are shown in Figure 84 at the top for the insulated breaker and at the bottom for the grounded breaker. Figure 85 shows the equipment on Dodge cars. The

breaker contact gap should be .020". The distributor is of the wipe contact type with a brush carried in the outer end of the rotor. The condenser is carried in the breaker housing, held by two nuts on the under



Figurt 84.—North East Insulated and Grounded Systems.

side of the housing and connected as shown by two leads.

The North East automatic advance mechanism is shown in Figure 86. It consists of a set of weights carried on pivots which are driven directly from the engine shaft. These weights are normally held in

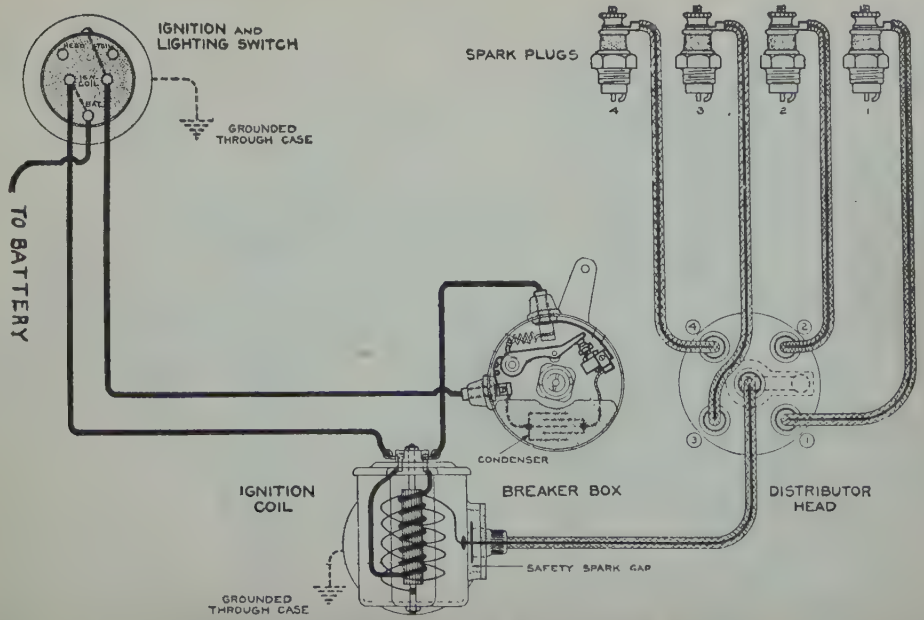


Figure 85.—Wiring of North East Ignition System.

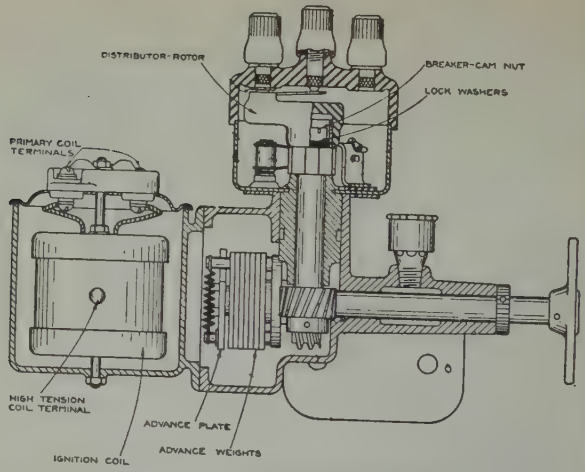


Figure 86.—North East Automatic Advance Mechanism.

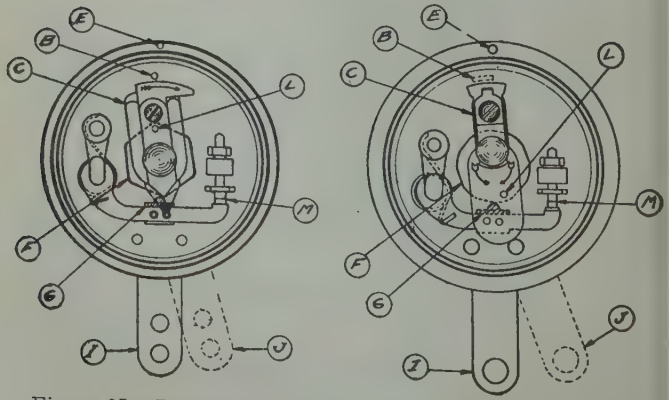


Figure 87.—Remy Breaker. B—Distributor Pin. C—Rotor. E—Distributor Cap Pin. F—Cam. G—Bumper. I—Retard. J—Advance. L—Rotor Drive Pin. M—Contacts.

place by small coiled springs against which the centrifugal force acts to rotate the vertical breaker shaft for a part of a turn relative to the driving shaft.

REMY

The standard construction of Remy breakers is shown in Figure 87. The breaker arm is carried on

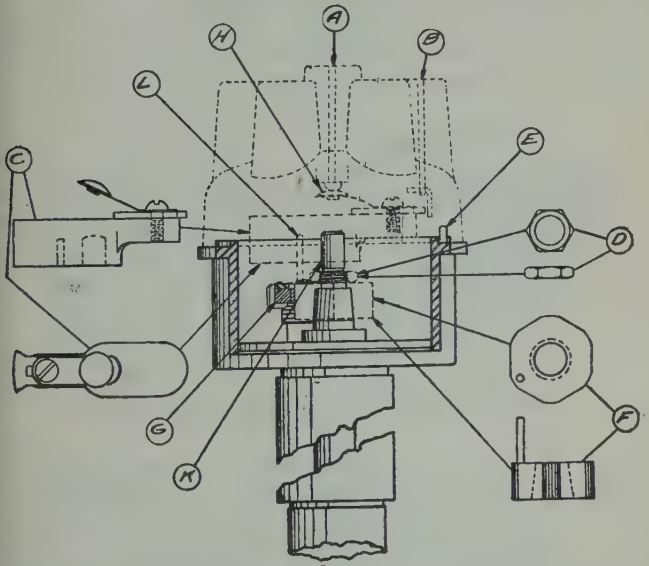


Figure 88.—Remy Ignition Head. A—Coil Terminal. B—Spark Plug Terminal. C—Rotor. D—Cam Nut. E—Distributor Cap Pin. F—Cam. G—Bumper. H—Rotor Spring. K—Rotor Shaft. L—Rotor Drive Pin.

a pivot. The contacts have a screw and nut adjustment and should be set with a gap of .020″. The cam has a tapered hole and is fastened on the top of the tapered breaker shaft with a small nut, as

shown in Figure 88. With this nut loosened, the cam may be lifted for turning while timing the ignition. A small pin on the cam engages a hole in the distributor rotor, providing a drive for the rotor from the top of the breaker shaft.

As may be seen in Figure 89, the distributor is of the jump spark type. The center terminal of the distributor connects with a small carbon brush on the under side of the head and this brush maintains contact with the spring button attached to the rotor segment. A safety spark gap is provided by placing a

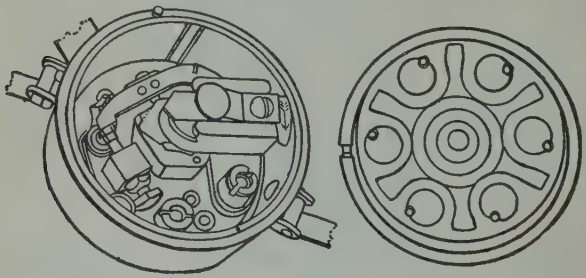


Figure 89.—Remy Breaker and Distributor Cap.

metal point on one end of the rotor segment, this point traveling about three-eights of an inch from the bottom plate, which is grounded.

The connections of the standard Remy coil are shown in Figure 90. The resistance unit is mounted on top of the coil and connected between the ignition switch terminal and one end of the primary winding A. The condenser B is carried in the coil and connected between the breaker terminal and ground. The high tension winding C is connected between the distributor terminal and ground. The breaker ter-

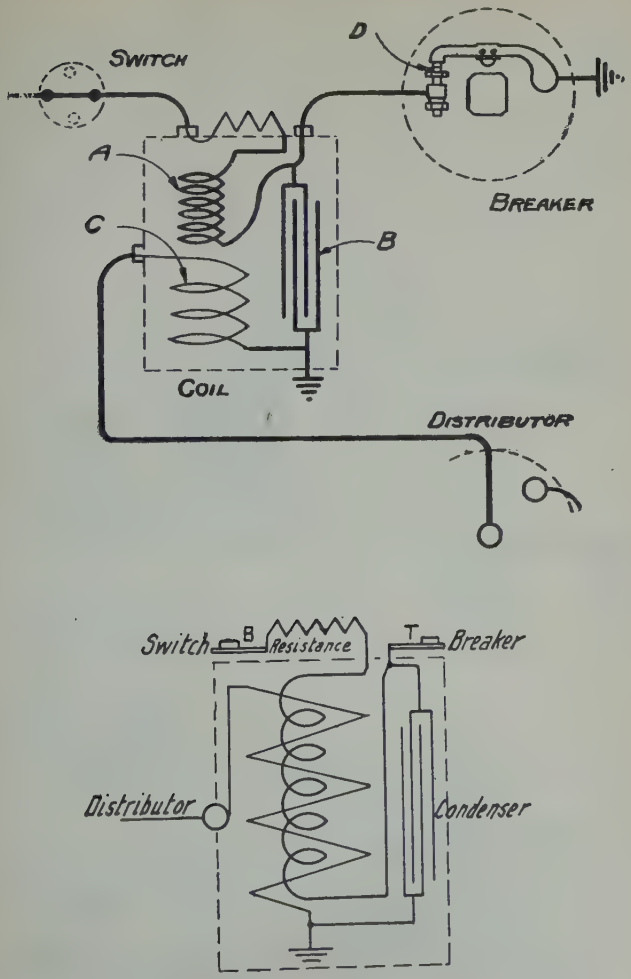


Figure 90.—Circuits of Remy Coil and Breaker.

minal is connected to the breaker contacts D. Some Remy coils have been built without condensers in their case.

Many Remy systems have an insulated breaker and use the reversing switch connections shown in Figure 91. A 12-volt system with a switch that connects the ignition first on one half of the battery, then on the other half, is shown in Figure 92 at the

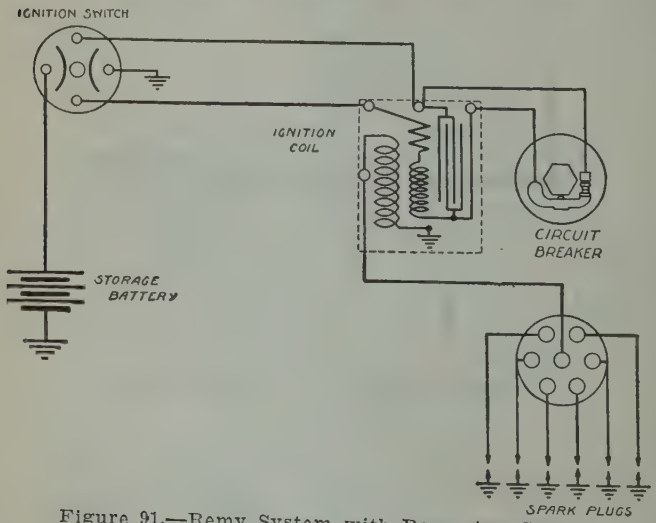


Figure 91.—Remy System with Reversing Switch.

top. At the bottom of Figure 92 is shown a twelve-cylinder system using a breaker having six lobes on the cam and two sets of contacts opening alternately, each set firing six cylinders.

The system shown in Figure 93 uses a coil without a condenser, carrying the ignition condenser in the housing with the regulator and cut-out for the gen-

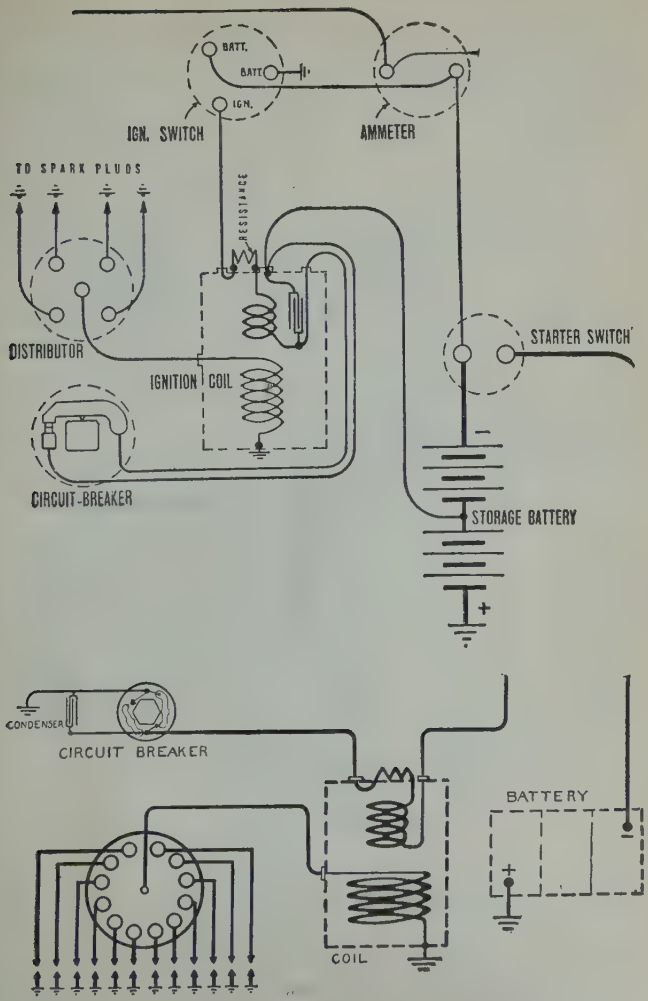


Figure 92.—Remy Ignition Circuits.

erator. The left hand terminal of the coil connects with the battery line.

Remy battery ignition systems have also been built

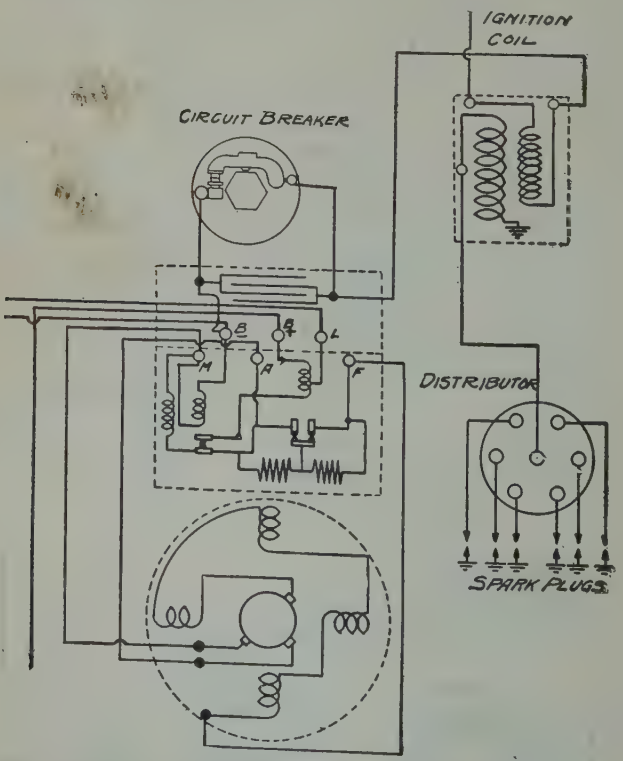


Figure 93.—Remy Ignition with Condenser in Regulator.

with a two-lobed cam driven at crankshaft speed and operating with a distributor driven faster than the speed of the breaker. Two of these systems are

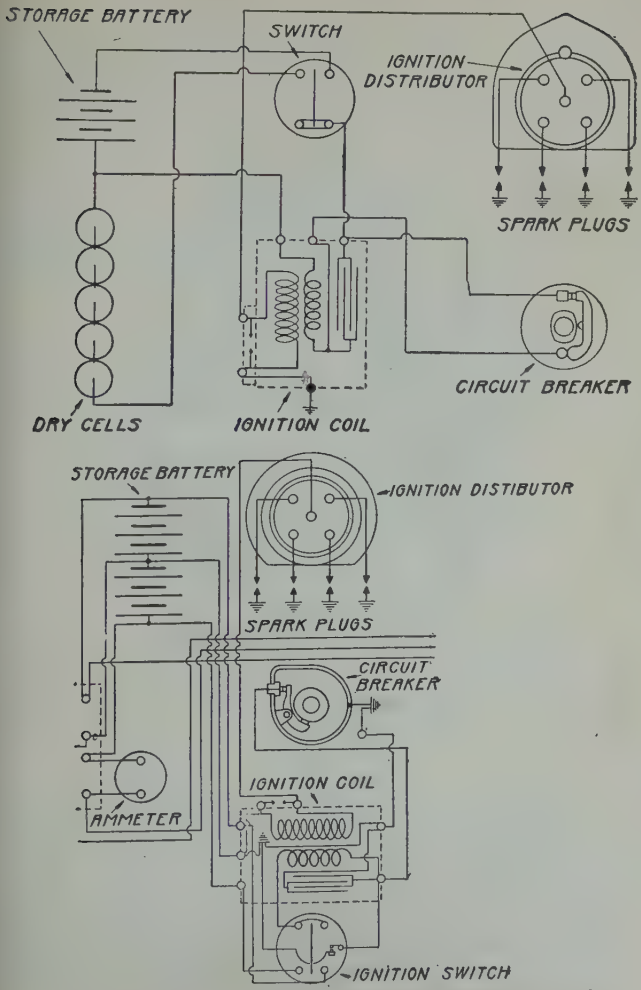


Figure 94.—Remy Systems with Magneto Types of Distributor.

shown in Figure 94. In the upper one the ignition unit appears like the breaker and distributor end of a conventional magneto. The system shown in the lower drawing is attached to one end of a generator with the breaker operated from the armature shaft.

WAGNER

The internal wiring and connections of the Wagner system are shown in Figure 95. The breaker gap has

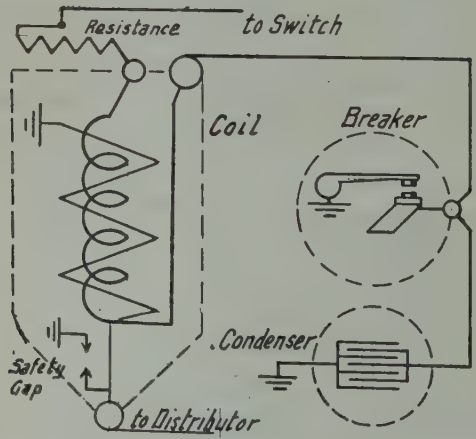


Figure 95.—Circuits of Wagner Ignition System.

a screw adjustment and should be set between .020″ and .025″. The breaker cam is held on the tapered top of the breaker shaft by a screw. With the screw loosened the cam may be lifted by prying with a screwdriver and turned for timing the ignition to the engine. The distributor is of the jump spark type with a carbon-button center contact as shown in Figure 96. The automatic advance mechanism carried

under the breaker and in the same housing may also be seen in Figure 96.

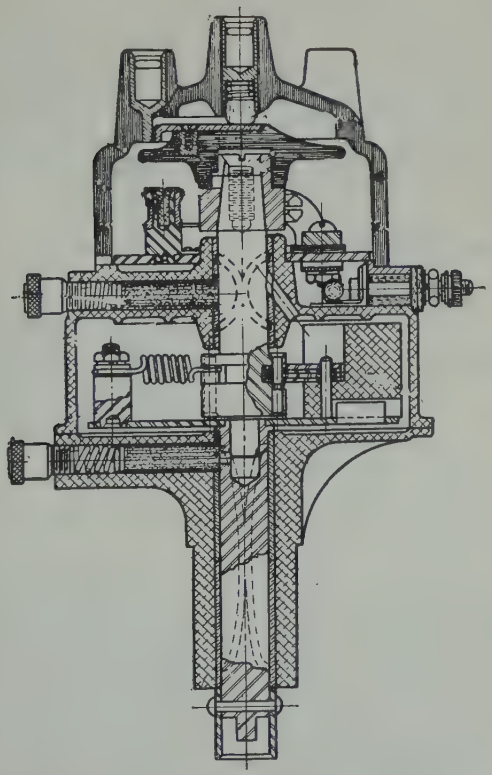


Figure 96.—Wagner Ignition Head with Automatic Advance.

The coil has a resistance unit mounted on the lower side and at the top has a safety spark gap near the

high tension terminal. The condenser is carried in a steel case and mounted directly underneath the breaker.

WESTINGHOUSE

The wiring of the Westinghouse SC type of ignition is shown in Figure 97. The resistance unit is carried on a porcelain cap mounted on top of the coil. The same coil is used for either 6-volt or 12-volt systems, the resistance unit being changed to suit the voltage.

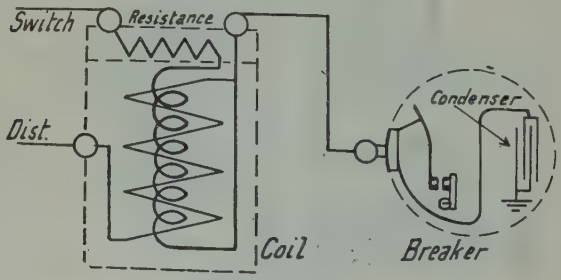


Figure 97.—Westinghouse SC Ignition System.

The breaker spring tension is adjusted by bending the spring support. The breaker contact gap is adjusted to between .012″ and .016″ by loosening the screw holding the stationary contact. The solid arm may also be bent to bring the contacts into line. The cam fits over a flat on the top of the shaft. The rotation of the breaker may be reversed by lifting the cam off the shaft and replacing it with the other side up. It is then necessary to move the contact arm so that it is one-eighth inch off center from a center line through the center of the shaft and the

terminal screw, this offset to be in the opposite direction to the rotation of the cam.

The condenser is carried in the breaker housing and connected between the screw holding the stationary contact and ground. The distributor is of the jump spark type.

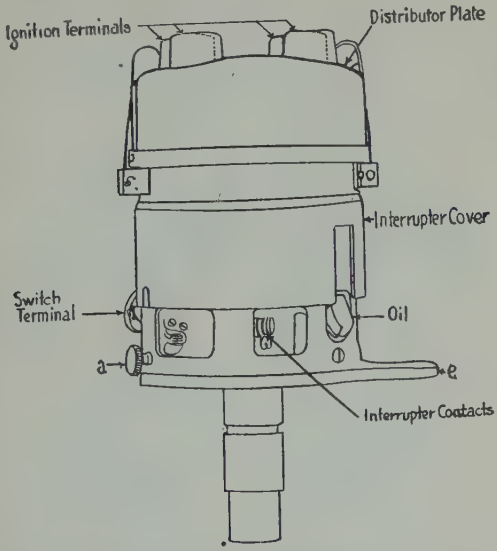


Figure 98.—Westinghouse Vertical Ignition Head.

Westinghouse Vertical Ignition Unit.—This unit, shown in Figure 98, includes the breaker, coil, condenser and distributor. The breaker, shown in Figure 99, is exposed by sliding a section of the housing upward. The cam is driven from the shaft through a small pin. The contact gap for the vertical unit should be set at .008″.

The distributor, at the top of the unit, is of the wipe contact type. The high tension winding of the coil, which is between the breaker below and the distributor above, is connected with a metallic ring which surrounds the vertical shaft just under the distributor rotor. At the outer end of the rotor are two round carbon brushes in a vertical tube, one above the other. The bottom brush bears on and travels around the metallic ring to which the coil winding attaches, while the top brush presses upward

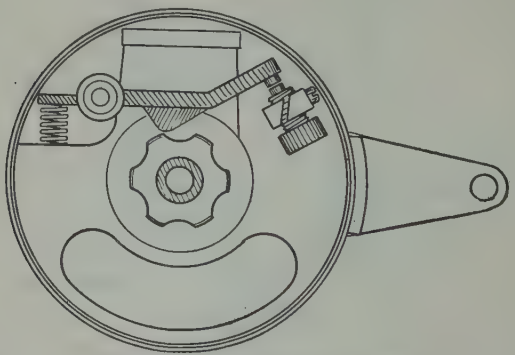


Figure 99.—Westinghouse Vertical Ignition Breaker.

against the track in which are located the segments for the spark plug lines. The secondary current is carried by the two brushes in the tube from the ring to the various segments as the pistons of the cylinders come into their firing positions. A safety gap is formed between the shaft and a metal piece, three-eighths of an inch from the shaft on the rotor.

As may be seen in Figure 99, the condenser is carried with the breaker opposite the contacts. The resistance unit is carried either in the fuse box, on

the ignition switch, or by a separate mounting. One resistance is used for 6-volt installations, another for 12-volt systems. For fuse box mounting the resistance is made up in the form of a three-eighth inch fuse and for switch mounting it is in a rectangular

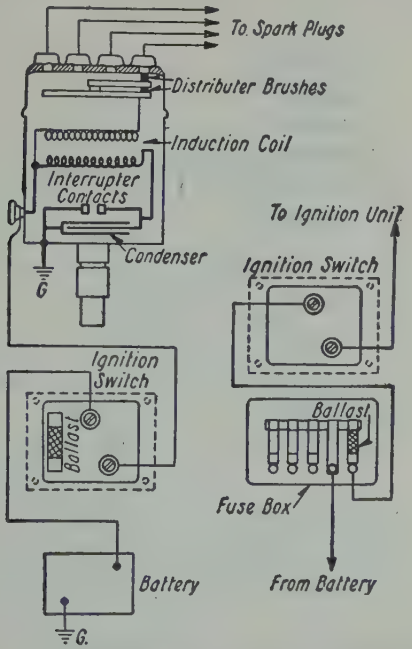


Figure 100.—Westinghouse Vertical Ignition with Single Terminal Head.

case. In Westinghouse systems the resistance is called the ballast. Complete wiring for the single primary terminal unit is shown in Figure 100 and for the unit with three primary terminals and a reversing switch, in Figure 101.

The instant at which the breaker contacts open may be found by removing the distributor cap and turning the shaft until the brush end of the rotor coincides with the V-shaped notch in the upper edge of the outer casing.

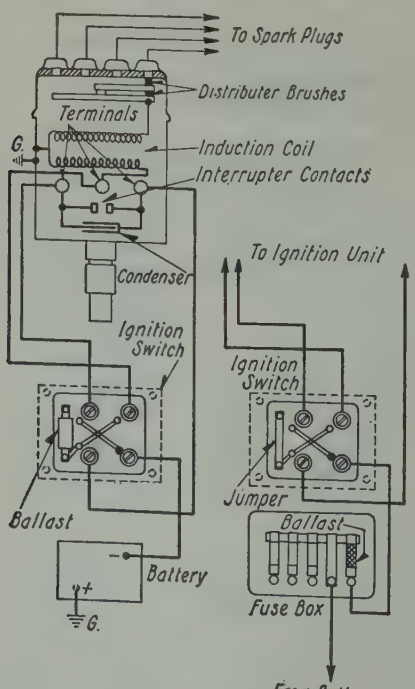


Figure 101.—Westinghouse Vertical Ignition with Three Terminal Head.

Ignition-Generators.—Early types of Westinghouse generators carried an ignition breaker, an automatic advance, and a distributor on one end of the genera-

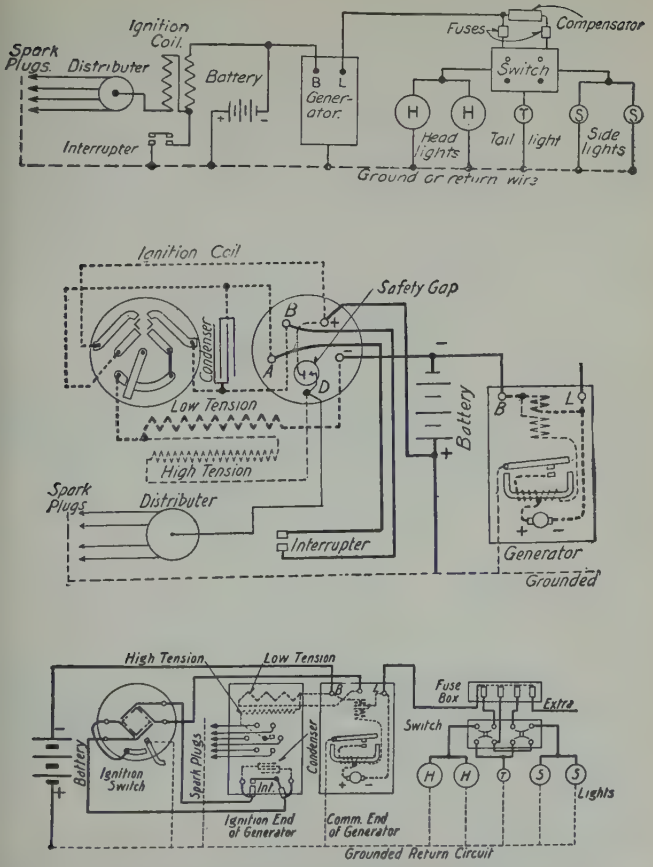


Figure 102.—Circuits of Westinghouse Ignition-Generators with Separate and with Self-Contained Coils.

tor, mounting the breaker on the armature shaft and driving the distributor by a gear from this shaft. In some equipments the ignition coil is also carried in the generator housing. Three types of this equipment are shown in Figure 102. The contact gap should be .005″ to .008″. Distributors are of the wipe contact type with carbon brushes. The separate coil contains a condenser.

BREAKER CONTACT GAPS

BATTERY SYSTEMS

Atwater Kent	
CC and CA, with sliding adjustment	.006″-.008″
CC and CA, with screw adjustment	.015″
Open circuit, C, F, H, K, K2, and K3	.010″-.012″
Auto-Lite	
IG types	.020″-.022″
Bosch	
T and TM types	.020″-.022″
Connecticut	
16, 17, and 18	.018″-.020″
Delco	
4-cylinder and 6-cylinder types	.020″-.027″
8-cylinder (except Cadillac)	.015″-.022″
8-cylinder Cadillac	.015″-.020″
12-cylinder	.020″-.025″
Kingston	
Type 30-A	.018″
North East	
Types O, P and S	.020″
Remy	
4, 6 and 8 cylinder	.020″-.023″
Wagner	
K types	.020″-.025″

Westinghouse

S. C. system	.012″-.016″
Vertical ignition unit	.008″
Ignition-generators	.005″-.008″

When two values are given, they are minimum and maximum limits. The best results will generally be obtained by making the setting midway between the limits.

Contacts should be cleaned, dressed, and aligned to make flat contact with each other before adjusting.

CHAPTER VI

FORD IGNITION

The ignition system used on the Ford car is entirely unlike any other equipment at present in use and requires individual and specialized treatment in all of its parts. This system includes a magneto which is in reality a small alternating current dynamo built into the engine flywheel. In connection with the magneto there is used a set of coils equipped with vibrators giving a stream of sparks, there being one coil for each cylinder of the engine. The ignition system is completed by a commutator which sends the magneto current to the proper coil at the proper time, and also the usual spark plugs and wiring between the various parts of the system.

THE MAGNETO

The Ford magneto consists of a set of sixteen V shaped permanent magnets which are mounted on the engine flywheel and which revolve with it, also a set of sixteen small coils wound on iron cores and held stationary on the engine crankcase in such a position that the set of sixteen magnets revolves with the outer ends very close to these coils. The appearance of these two parts is shown at the bottom of Figure 109.

The sixteen permanent magnets are so placed that the adjacent ends of any two magnets are always of the same magnetic polarity. Each magnet is mounted

in such a way that its positive pole is next to the positive pole of the magnet at one side and so that its negative pole is next to the negative of the magnet on the other side. The whole arrangement, as shown in Figure 103, then becomes in effect a compound magnet having sixteen outward pointing poles, eight of them positive and eight negative. The magnetic lines of force passing out of any pair of adjoining positive poles travel to the negative poles which are found on either side of the positives. From eight of the poles (the positives) the magnetic lines of force are then traveling outward, and to eight more of the poles (negatives) the lines are traveling inward.

It was explained in Part I that a current of electricity will be induced in a coil of wire wound on an iron core if the magnetism of the core changes in intensity or reverses its direction entirely. If then a coil carried on an iron core were moved around the circle formed by the ends of the magnets and with the end of the coil's core always pointing toward the magnet poles, a flow of current would take place through the coil each time the flow of magnetism through the core changed its direction. In the case of the Ford magneto there would be sixteen separate impulses of current because the direction of the magnetic lines of force would change in its flow each time the coil moved from a magnet end of one polarity to an end of the opposite polarity. As the coil passed from in front of a positive pole to a negative pole, the flow of current would be in one direction through the coil winding, and as it passed from in front of the negative pole toward another positive the flow of current through the coil winding would take place in the opposite direction. The current would there-

fore be of the alternating type because of this change in the direction of flow.

In the construction of the Ford magneto there are sixteen of these coils spaced the same distance from each other as are the ends of the magnets. One continuous winding passes around all of the sixteen coils as shown in Figure 103, and this winding reverses its direction of turning around the core in each alternate coil. As this set of sixteen coils is stationary, the same effect is secured by moving the magnets in front of the coils, as would be secured by moving the coils in the explanation already given. During one sixteenth of a full revolution of the flywheel with its set of permanent magnets, the end of any one magnet will pass from one coil to the next and a flow of current will be induced in the coil windings. It has already been stated that the direction of induced current flow reverses its direction in the coil windings with change of the magnetic polarity, but inasmuch as the winding itself is also reversed on alternate coils, the direction of flow through the whole length of the winding will be in one direction during this sixteenth of a turn. Then on the next sixteenth of a turn, as the magnets each pass to another coil in their rotation, the current through the whole length of winding will reverse its direction. One end of the coil winding is grounded and the other end is led to a terminal on top of the flywheel case from which the magneto current passes to the remaining parts of the ignition system.

The magnets are fastened to the flywheel at their inner ends by means of bolts through the bottom of the V and at their outer ends are fastened by iron plates, each plate holding two adjacent magnet ends

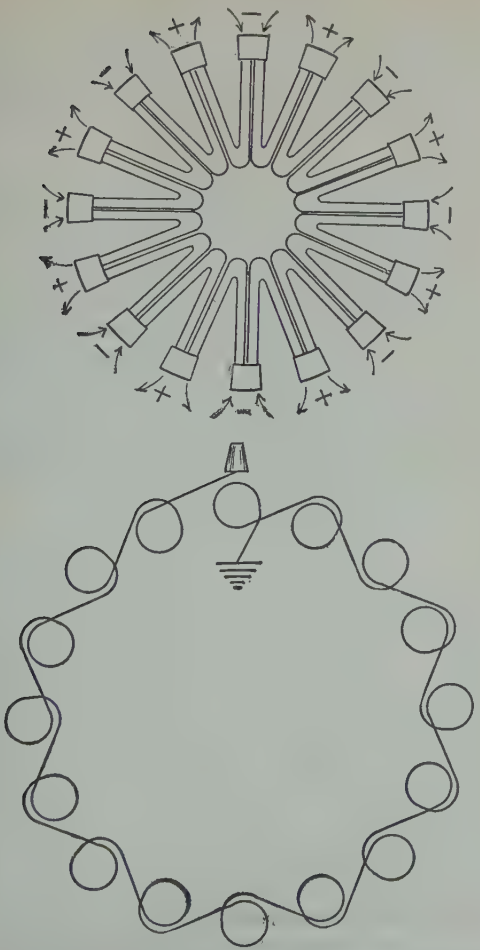


Figure 103.—Principle of the Ford Magneto. Top: Permanent Magnet Rotating Field. Bottom: Winding of Stationary Armature Coils.

of like polarity. This metal clamping plate serves to make the two poles which are held by it into a single pole of either polarity and from this single pole the magnetic lines of force issue if it is positive, or return if it is negative.

The winding of the magneto coils consists of a copper ribbon covered with a fabric insulating covering which is treated to make it moisture and oil proof. This winding is attached to the ring carrying the coils at one of its ends so that a ground connection is established for one terminal and the other end of the winding obtains electrical connection with the flywheel case terminal by means of a small brush backed by a coiled spring, the combination being carried in an insulating holder fastened to the flywheel housing by means of a flange and screws. The inner end of this brush bears against the connection from the winding ribbon.

The current from the Ford magneto changes its direction of flow sixteen times during each complete revolution of the flywheel, that is, it makes eight complete cycles or changes from positive to negative and back again to positive. The number of cycles at which the current is being delivered at any given time will therefore be eight times the number of revolutions per minute that the engine crank shaft and flywheel are making. The voltage from the magneto varies from zero with the engine idle to something over thirty at forty miles an hour. At a car speed of $3\frac{2}{3}$ miles an hour the voltage rises to six which is about the lowest pressure at which satisfactory ignition action is obtained. At ten miles an hour the voltage is approximately twelve, at twenty miles an hour it is slightly over twenty and at thirty miles an hour

the voltage is about twenty-eight. These figures are for the new type of magneto which is designed to operate the head lights as well as the ignition.

VIBRATOR AND COIL

The coil used on the Ford car is of the multiple unit vibrating type having one complete induction coil unit for each of the four cylinders and having a magnetically operated breaker of the vibrating type on each coil. This equipment was at one time almost universally used in connection with dry cells, a storage battery or a low voltage dynamo for automobile ignition but today it is found on the Ford car alone.

A diagram of the coil and its circuits is shown in Figure 104. By following the primary and secondary current paths the action of this unit and of the vibrator may be easily understood. With the switch closed in the position shown by the dotted lines, primary current will flow from the magneto terminal on top of the flywheel case through the wire 1 to the switch and wire 2 to the one terminal of the primary winding. Entering the coil box by this terminal the primary current will flow around the primary winding of the coil and will strongly magnetize the core of the coil which is made up of a number of iron wires formed into a cylindrical bundle inside the winding. Leaving the coil, the current flows through wire 3 to a spring blade B which is carried with one of its ends above, but not touching, the core of the coil. This spring blade is made from steel and is accordingly attracted by the magnetism induced in the iron core by the passage of the primary current.

Just above the spring blade is a stationary brass bar called the bridge and the contact points C are

carried by these parts, one contact by the spring blade and the other by the stationary bridge. The primary current flowing through the blade passes across the contacts, which are normally closed, and enters the bridge. From the bridge the current flows by way of wire 4 to the commutator which is a device consisting of a revolving roller inside of a housing, the roller being driven from the engine and making successive contacts with a series of segments set into the inside of the housing. The wire 4 connects with a segment, only one of which is shown for purposes of explanation. The revolving roller of the commutator is one of the metal parts of the engine and the current therefore flows through the segment and the roller to the ground or metalwork. As has already been explained, one end of the coil winding of the magneto is connected with the ground and the primary current returns by this metallic path to the magneto coils, thereby completing the ignition circuit starting with the magneto and returning to it. Each time the commutator roller rides over and makes contact with one of the segments a circuit will be established through the coil whose winding is connected with this segment.

As soon as the commutator allows current to flow through the coil and around the primary winding by way of the wires and the vibrator contacts, the core of the coil becomes magnetic and attracts the spring blade B. The end of the blade that carries the contact point is then pulled down toward the upper end of the core and the contacts are caused to separate inasmuch as the bridge A remains stationary. With the contacts separated the primary current path is opened and the current no longer flows. With no current flowing the core of the coil is no longer magnetic and

the blade B is released, again closing the contacts by returning to its former position and allowing a further

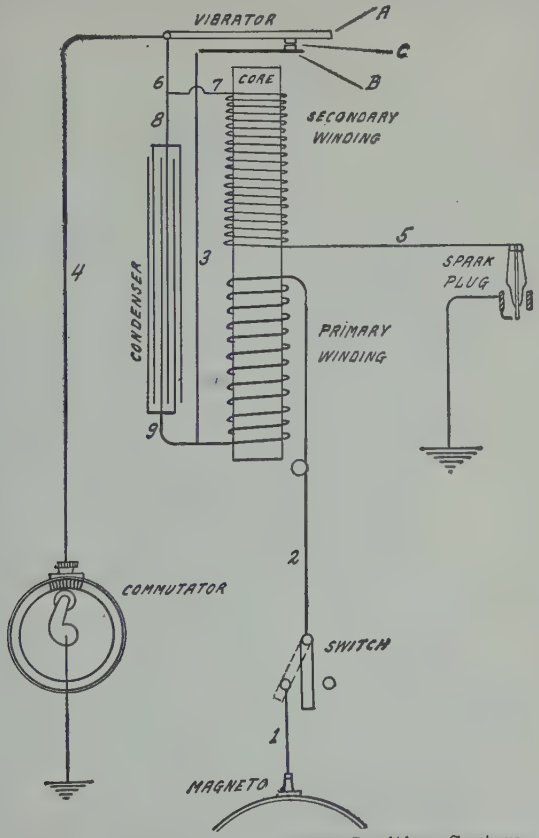


Figure 104.—Circuits of Ford Ignition System.

flow of current. This further flow again magnetizes the core and the action continues with the contacts

opening and closing with exceeding rapidity, in fact the action of the blade is to vibrate. Each opening of the contacts stops the flow of current through the coil and allows the core to become demagnetized, while each time the contacts close the core is again magnetized. This change in magnetic strength of the core induces the current of high voltage in the secondary winding which is also wound around the iron center and this high tension current is led through the wire 5 to the spark plug. A high tension current is induced in the secondary winding each time the contacts separate and the result is a shower or stream of sparks between the points of the plug.

The secondary circuit starts in the winding of the coil, passes through wire 5 to the central electrode of the spark plug and by forming the arc between the spark plug points reaches the metal shell of the plug which is a ground connection in contact with the metal of the engine. Passing through the metal work, the secondary current reaches the revolving roller of the commutator, through the roller it passes to the segment with which the roller is then in contact and by way of the wire 4 to the coil box. Entering the coil box the secondary current follows wires 6 and 7 back to the other end of the secondary winding from which it originally issued to the spark plug wire. It will thus be seen that the high tension current follows the same path as does the low tension between the commutator and the coil.

The condenser is electrically connected between the two contact points of the vibrator so that the induced current of the primary will be absorbed on the break of the contacts and given back to the primary winding of the coil as in any other ignition system making use

of a breaker. The condenser is connected with the contact point on the stationary bridge of the vibrator by the wires 6 and 8 and to the contact point on the spring blade by the wires 3 and 9.

The construction of one form of Ford coil is shown in Figure 105, the numbers being the same and referring to the same wires as in the preceding Figure, but in this case the parts are shown in the relative positions that they occupy in the wood box which encloses them. The terminals marked 2, 4 and 5 are flat brass discs on the surface of the box and these discs bear against three spring contacts which complete the circuits to the outside connections when the coil unit is in place in the housing which carries the four coils. The box is filled with insulating compound to hold the various parts in position. As will be noted from the illustration, the primary winding is carried for the entire length of the iron wire core while the secondary winding is shorter and placed around the outside of the central portion of the primary. The condenser is built up of waxed paper and tin foil and is then folded into a compact roll. Between the condenser and coil is a piece of glass one-fourth of an inch thick which provides effectual insulation for the high tension current.

The only adjustment of the vibrator is that controlling the gap between the contact points when they are opened. This adjustment is made by turning the knurled nut D up or down on the screw G. Adjustment may be necessary because of increase of this gap due to wear or burning. Before making any adjustment the contact points should be examined and if they are found rough or pitted they should first be filed flat with a very thin file. This operation may

also be performed by drawing fine emery cloth between the contacts while they are held together, first with the emery side up and then down. After dressing the contacts the adjusting nut should be turned until, with the contacts held apart their full distance,

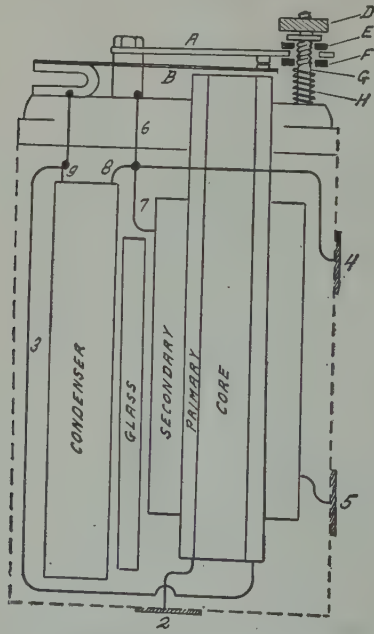


Figure 105.—Internal Connections of Ford Vibrator and Coil Unit.

the points will be twenty-five thousandths of an inch, or a little less than a thirty-second apart. E and F are fibre washers which insulate the bridge A from the adjusting screw. The adjustment is maintained

by the tension of the spring II acting against the threads of the nut.

COMMUTATOR

In the Ford ignition system the time at which the spark occurs is determined by the commutator, which, in one sense, takes the place of the breaker mechanism of the usual equipment in timing the spark. From the explanation of the action of the coil and vibrator it will be seen that the spark will pass at the plug points as soon as the commutator roller touches one of the segments and this must occur when the piston of one of the cylinders in which the plug is located reaches top center at the end of its compression stroke.

The Ford commutator, shown in Figure 106, consists of a metallic roller attached to the forward end of the cam shaft so that it turns with this shaft and at one half the crank shaft speed of the engine. This roller is carried inside of a circular housing made of insulating material and into which are set four metallic contacts or segments. The roller touches these segments in turn as it revolves inside the housing. To each of the four segments is attached a terminal or binding screw which appears on the outside of the housing and from each terminal a wire leads to one of the coil units.

It will be recalled from the explanation of the action of the engine that the cam shaft makes one revolution for each two revolutions of the crankshaft and that for each complete cycle of strokes in any one cylinder the cam shaft makes one full turn. Bearing in mind that the commutator roller is fastened to one end of the cam shaft and taking any one of the commutator

segments as an example, it will be seen that the roller will touch this segment once for each complete cycle in one cylinder. Thus, for each power stroke in the cylinder considered, there will be a complete circuit

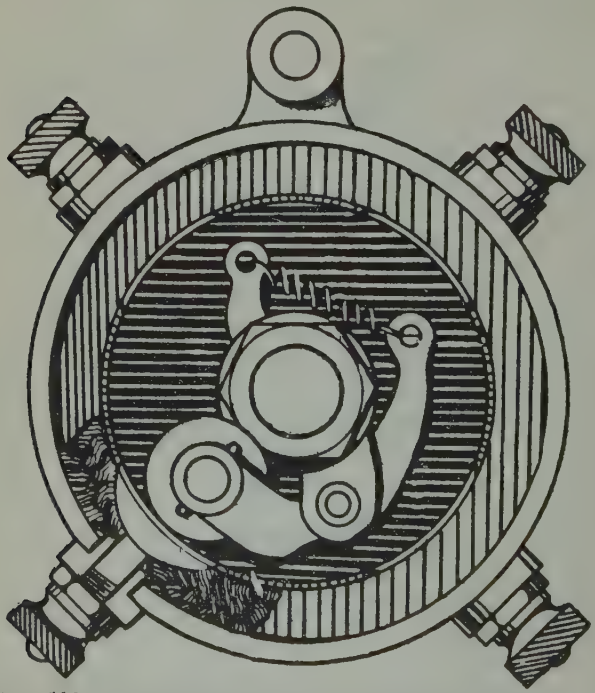


Figure 106.—Commutator or Timer of Ford Ignition System.

through the commutator, the coil and the magneto and a stream of sparks will be produced at the plug.

The roller in the commutator is placed in such a position on the cam shaft that it makes connection

with one of the segments each time that a cylinder is ready to fire and the segment with which connection is made is the one from whose terminal a wire leads to the coil used with the spark plug of the cylinder that is then ready to fire. The next contact in the commutator with which the roller engages is connected with the coil whose spark plug fires the cylinder next to deliver power and so on for all four segments and all the cylinders.

WIRING AND TIMING

The external wiring and its connections through the coils and magneto winding are shown in Figure 107. The coil terminals are shown as they appear from the engine side of the dash and the commutator terminals as they appear from in front of the engine. The engine cylinders with their spark plugs are numbered from 1 to 4, number 1 being toward the radiator and number 4 next the dash.

From the magneto terminal the primary current passes through the switch when it is closed on the magneto side to a common bus connection in the coil box. This common connection carries the current to the terminals on the bottom of the four coil units and this bottom terminal leads to one end of the primary winding. Inasmuch as the vibrators do not require any additional outside connections or wiring they have been omitted from the diagram. After passing through the primary circuit of the coil the current leaves the unit by way of the upper terminal button of the coil case and passes through one of the wires leading to the commutator, just which wire depending on which of the commutator segments the roller is then in contact with. From the commutator roller

the primary circuit is completed through the metal back to the magneto. The secondary wires to the spark plugs are attached as shown in the diagram; that from number one cylinder leading to the coil toward the right of the car (observed from the driver's seat), the wire from number two plug to the second coil from the right and so on. The firing order of the engine is cared for by crossing the wires between the commutator and coil rather than the wires from the coil to the plugs.

To properly time the commutator the following method may be used: First place the spark control hand lever, which is underneath the steering wheel, two notches on the quadrant from its fully retarded position. In the retarded position the lever is forward or away from the driver and to make ready for timing it should be moved two notches toward the rear of the car. The piston of number one cylinder should then be brought to top dead center between the compression and firing strokes, this position being determined by observing or feeling the rise of the piston through the opening left by removal of the spark plug. The cover of the commutator should then be removed and the position of the roller observed. This roller travels in a left hand or anti-clockwise direction, that is, in a direction opposite to that of the crank shaft. The timer housing should be moved, without disturbing the position of the hand control lever, so that the roller is just making contact or just about to make contact with the segment attached to the terminal at the left of the control rod lever, this being the terminal used for firing number one cylinder. The roller should be found very nearly in this position provided it is correctly attached to the end

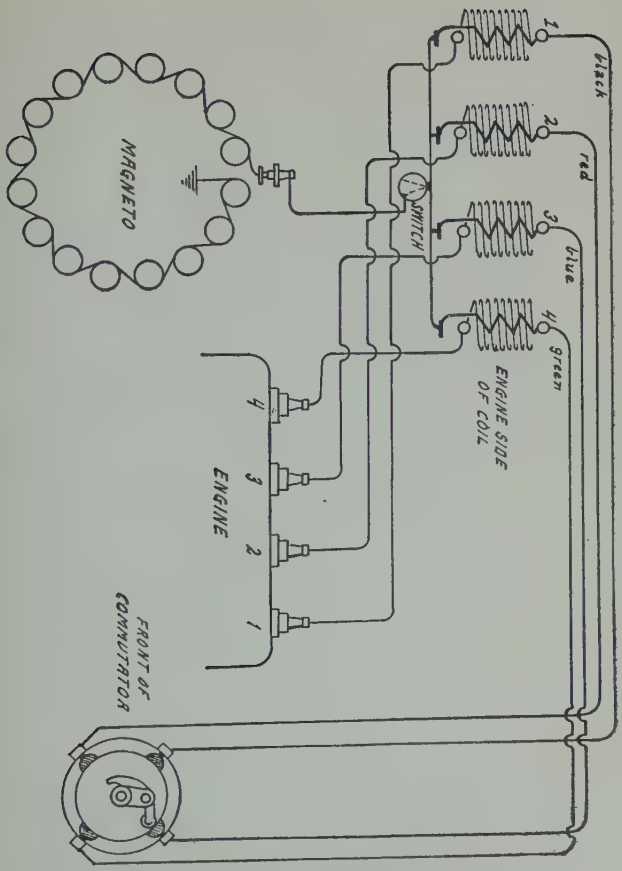


Figure 107.—Primary and Secondary Circuits of Ford Ignition System.

of the valve cam shaft and the slight adjustment that may be necessary can be made by altering the length of the control rod between the commutator and the lower end of the steering gear rod, this alteration being either by the screw adjustment or by bending the rod.

A wire should then be attached to the terminal mentioned and run to the low tension terminal at the upper end of the right hand coil, this being the terminal in the upper row of four which is toward the right hand side of the car. In case the colored cables are used this wire for number one cylinder will be black. As the roller turns in the direction it is driven by the engine it will next make contact with the segment for the terminal just below the one already connected and from this second terminal a wire (red) should be run to the upper coil terminal second from the right hand side of the car. The firing order of the Ford engine is 1-2-4-3 and the wire (green) from the next commutator terminal in the direction of rotation will therefore be connected to the coil for number four cylinder, which is the coil toward the left of the car. The remaining terminal will then be connected by its wire (blue) to the coil for number three cylinder.

TROUBLES AND REMEDIES

In case of misfiring in one or more cylinders the particular ones at fault may be located by manipulation of the coil vibrators. The throttle should be opened sufficiently to allow the engine to run at fair speed and while thus running, the vibrator blades of the two outside coils, number one and number four, should be held with the finger tips. Number two and

number three cylinders are thereby allowed to fire while one and four are cut out. If, from the sound of the exhaust, it is found that two and three are firing regularly the trouble should be looked for on either number one or number four. While still holding number four vibrator, that for number one may be released and if the cylinder then picks up and fires regularly a similar procedure should be gone through with by releasing number four and holding number one. It will be finally found that the vibrator for one or more of the cylinders may be held or released without causing any change in the running of the engine and it will thereby be known that the cylinder connected with this vibrator which shows no change in running is the one in which, or in whose connections, the trouble exists. Having located the cylinder in trouble its spark plug and coil vibrator should be looked to first.

The plug insulation inside of the shell should be clean and free from soot, oil or moisture, the insulation should be unbroken and the gap between the electrode points should be very close to 1/32 of an inch. It will also be advisable to clean the portion of the insulator which extends outside of the cylinder and shell. The spark plugs and high tension wiring of the Ford are no different from those of any other car and the general troubles to which these parts of the equipment are subject should be checked according to the general instructions on troubles and remedies in Chapter IX.

The vibrator should be examined to see that the contact points are not worn, dirty, sticking or badly pitted. If any of these conditions are found the contacts should be dressed by drawing a strip of fine

emery cloth between them, first with the emery facing up and then down. With the contacts in proper condition the correct adjustment may be made by screwing the adjusting nut up until the contacts are allowed to separate. The nut should then be slowly turned down until slight tension has been placed on the spring blade or until the cylinder connected with this coil fires regularly. It is possible that the coil unit or the coil box have become wet, allowing a short circuit, or that some of the connections inside of the coil box have become loose.

With the vibrators adjusted, the coil unit for the cylinder at fault may be lifted out of the box and exchanged with another unit of a cylinder which is firing properly. If this changes the misfiring to the cylinder now connected with the coil which was originally connected with the first cylinder in trouble, the trouble is evidently with the coil or its vibrator. The defective coil should then be removed from the case and tested as shown in Figure 108. Terminal A is that through which the magneto current enters the coil, terminal B is the high tension lead to the spark plug wire and terminal C is used for the connection to the timer wire and through this same wire for the ground connection of the high tension winding of the coil. With a wire held firmly on terminal C and with its other end about one quarter inch from B, a spark should pass across this gap to B whenever a six volt storage battery or a battery composed of five dry cells is connected and disconnected with terminals A and C as shown. If, by changing the vibrator adjustment, it is still impossible to secure a spark, the fault lies within the coil or in the parts of the vibrator. If the fault is inside the coil unit the most satisfactory

remedy is the installation of a new unit because the windings, the condenser and their connections are imbedded in an insulating compound that makes the work of repair inside the unit more costly in time consumed than the price of a new coil and vibrator.

There are but few troubles that affect the Ford magneto and in case it is determined that insufficient current or no current at all reaches the coil box it will be first in order to remove the terminal contact

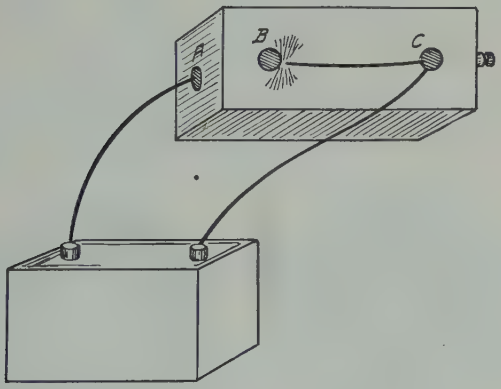


Figure 108.—Testing Ford Coil Unit with Battery.

which is carried on top of the flywheel case. It may be found that dirt has collected at the lower end of this contact brush and with this foreign matter cleaned away normal action will be resumed. If the car is an old one or if the engine has recently been disassembled and rebuilt it is possible that the permanent magnets of the magneto have become weakened and it will be found most economical to replace them with new ones. The magnets should be assembled on the

flywheel so that the negative poles of adjacent magnets are together, this also bringing the positive poles together, that is to say, magnet ends of like polarity should be together in all cases. In assembling the magnets the polarity may be determined by the use of

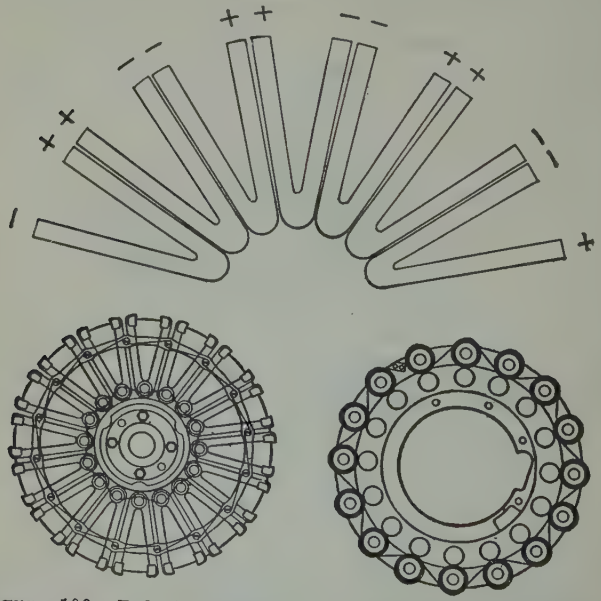


Figure 109.—Relative Positions of Parts of Ford Magneto. Top: Placing of Magnet Poles. Lower Left: Magnet Assembly on Fly Wheel. Lower Right: Coils Mounted on Stationary Ring.

a compass, making sure to place two ends together that both attract the same end of the compass needle. A simple way to make sure of correct assembling is to bring the magnet ends close together while they are off the flywheel and place together the poles or

ends which do *not* tend to draw together. If two magnets are held in this way with one end of one magnet close to an end of the other, it will be found that the ends either have strong attraction for each other or else that they have no attraction or even a repulsion. The magnets should be placed on the flywheel with the ends together which have no attraction for each other, the polarities then being as shown at the top of Figure 109.

It is possible to remagnetize the permanent magnets of the Ford magneto without disassembling them by

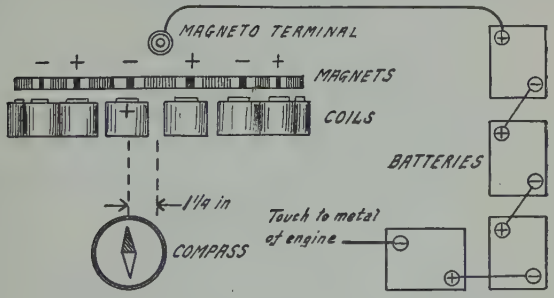


Figure 110.—Recharging Permanent Magnets in Ford Magneto.

the method explained and shown in Figure 110. The magneto coils are used as energizing electro-magnets and with the permanent magnets in position so that their poles are directly opposite the ends of the cores in the coils the remagnetizing may be done by passing a heavy current through the coils.

One of the coils in the magneto, the one from which connection is made with the flywheel case terminal, is about 1 1/4 inches to the left of the center line drawn lengthwise through the terminal post. With

the battery connected as shown the current will flow through the coils in such a way that the first coil to the left of the center will be made an electro-magnet with its positive pole toward the permanent magnets, this being the proper relation of the electro- and the permanent magnets for the operation.

To perform the operation it is first necessary to secure an ordinary pocket compass and hold it near the rear side of the flywheel housing and with its center about 1¼ inches to the left of the center line of the engine which is known from the position of the magneto terminal. With the wire disconnected from the magneto terminal and the compass in position, slowly crank the engine until the North pole of the compass needle points straight ahead as shown, this indicating that the South or negative pole of a permanent magnet is directly in front of the compass and therefore directly in front of the core of the first coil. The correct relation of all the parts is shown in the illustration.

A direct current of from twenty to thirty volts pressure is required and this may be conveniently secured by connecting four six-volt storage batteries in series, or any number of storage batteries or dry cells which will deliver the desired voltage may be employed. The positive terminal of the series of batteries should then be connected with the magneto terminal on top of the flywheel and a length of wire attached to the negative terminal of the batteries. With the magneto parts in the positions described, the end of the length of wire from the negative terminal of the batteries should be touched to the metal of the engine, held there for not more than one or two seconds and then removed, this operation of touching the metal being repeated

from ten to fifteen times. Each time the connection is made and broken the engine will be felt to jar noticeably, this being caused by the attraction between the coils and the permanent magnets. This operation will increase the strength of the permanent magnets and if weakness was the cause of the difficulty a remedy will be effected. The remedy is not, however, as satisfactory as that secured by replacing the old magnets with new ones.

If ignition trouble is noticeable only when running at high speeds the commutator should be examined. The surface of the circle around which the roller travels should be clean and smooth so that the roller can make good contact with each of the segments with moderate tension on the coil spring. In case the cleaning of the commutator ring does not effect a remedy, and if the fibre, the roller or the segments are badly worn and show pitting, the most satisfactory remedy will be to replace the defective parts with new ones. It is assumed that the small coiled spring is strong enough to maintain a firm contact between the roller and segments under all conditions.

It may be found that the lubricant used in the commutator has become thick or hard, this being especially noticeable in cold weather. Such a condition will prevent the roller from making good contact with the segments, especially at low engine speeds and when the car is first started. This trouble may be overcome by using a lubricant composed of three-fourths lubricating oil and one-fourth kerosene, or by using any of the very light machine oils that are on the market.

In examining the commutator see that the roller is free to revolve on its pin and that the arm does

not stick in any one position when moved by hand. These difficulties may be removed by cleaning and oiling and, if necessary, by increasing the tension of the coiled spring. It is also possible that the roller arm or roller sleeve is loose on the forward end of the shaft, this indicating play in the key or nut which holds it in place.

The wiring, both low and high tension, should be examined for defective insulation, broken strands, short circuits, accidental grounds and all of the usual troubles found in the connections. The connection of the wires between coil and commutator should also be examined to make sure that they correspond with the firing order of the engine and with the connections shown in the wiring diagram.

The condition of the Ford magneto may be accurately tested with the form of portable alternating current voltmeter, shown at the lower left in Figure 111. This instrument is fitted with a cord ending in a special test point which is pushed against the metal around the terminal on top of the flywheel case. The ring near the end of the handle then makes contact with the upper end of the flywheel case terminal so that the magneto voltage causes a reading of the meter. The engine should be run at a speed corresponding to twenty miles an hour while taking the readings.

A reading below 11 volts indicates that the magneto needs overhauling; a reading between 11 and 17 volts will possibly give good ignition, but shows the magneto to be in poor condition. From 17 to 24 volts the magneto will give good performance, and from 24 to 30 volts it is in exceptionally good condition.

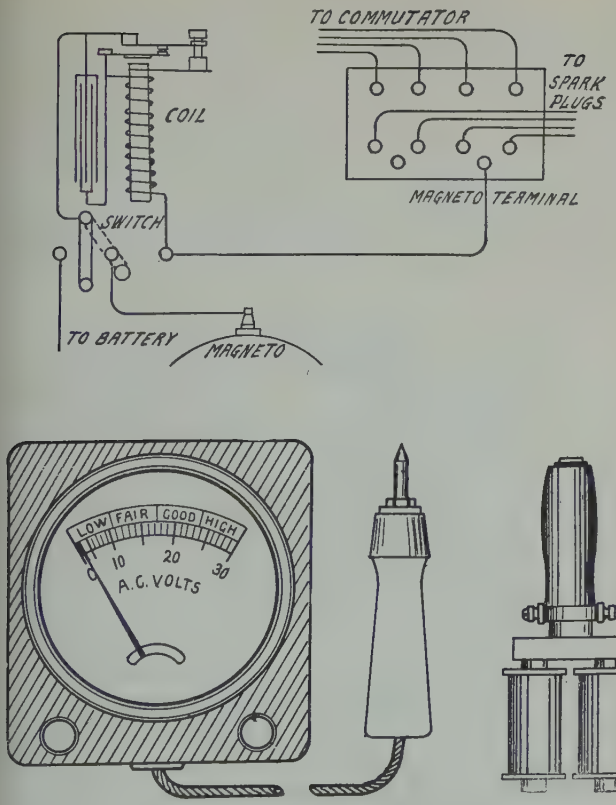


Figure 111.—Top—Circuits of Master Vibrator on Ford Car. Bottom—Magneto Meter and Magneto Remagnetizer for Use on Ford Car.

In the lower right hand corner of Figure 111 is shown a form of re-magnetizer especially designed for handling the Ford magneto. The terminals on the

side of the handle are connected with a 6-volt storage battery, the poles of the magnet are then placed on the poles of the V-shaped magneto magnets, and the button in the end of the re-magnetizer handle is pressed to complete the magnet circuit. The poles are applied so that they pull hard against the magneto magnets. The engine is cranked a little at a time, making application of the magnetizer as the magnets come into view through the transmission cover plate opening.

MASTER VIBRATORS

In connection with the Ford coil an additional coil consisting of only a low tension winding, a condenser and a well constructed vibrator may in some cases be employed as a fitting attached after delivery of the car. The connections and internal wiring of such a device are shown in Figure 111. In making the attachment the vibrators of the Ford coils are rendered inoperative and the two parts carrying the contact points are permanently connected, this being accomplished by screwing the adjustment down tight, or, preferably by attaching a short length of wire such as a dry cell connector from the brass bridge which carries the upper contact to the brass base upon which is mounted the spring blade carrying the lower contact. The current which formerly passed across the contacts themselves will then take the path through the length of wire and complete the primary circuit through the coil at all times, regardless of the position of the vibrator parts and contacts. Such a connection makes of the Ford coils simple induction coils with a high and low tension winding.

With the master vibrator connected in the ignition circuit as shown, the primary current from the mag-

neto passes to one of the terminals of the vibrating coil and to one of its contact points. From the other contact point the primary current travels through the winding about the core of the master coil and the ordinary vibrating action is set up. This pulsating current then passes from the terminal of the master vibrator to the primary windings of the four unit coils, entering them through the terminal and path formerly connected directly with the magneto. In accordance with the position of the commutator the pulsating current induces high tension impulses in the secondary windings of the Ford coils, this current being led to the spark plugs in the usual way.

The master vibrator is usually constructed with its own switch, this switch being designed to connect with the magneto as one source of current and with an auxiliary storage battery or set of dry cells as the reserve source. With a switch incorporated in the master vibrator the switch on the Ford coil is allowed to remain in the position that makes connection with the terminal (magneto or battery) which has been connected with the master coil.

The advantage in using a master vibrator is that the action in inducing the secondary current is of necessity uniform for each of the four coils and the adjustment once correctly made for the single vibrator insures its correctness for each of the four cylinders. The objection to the device is that the additional resistance introduced by the additional length of wire in the primary circuit reduces the efficiency of the ignition, although with the surplus of current generated by the Ford magneto this is not in reality a serious drawback.

REVIEW OF CHAPTER VI

FORD IGNITION

The Ford magneto generates alternating current with sixteen V-shaped magnets carried on the flywheel with their poles rotating 1/32 inch from the cores of sixteen ribbon-wound coils which remain stationary.

The coils have their direction of winding reversed for each alternate one. One end of the coil circuit is grounded and the other connects with a terminal on top of the flywheel case.

The **magnets are mounted** so that adjacent ones have like poles together.

The Ford **ignition coils** have magnetic vibrators on top of each unit and connected in the primary circuit. The **condenser** is mounted in the coil case.

The vibrator is adjusted by turning the screw up until the contacts separate, then turning it down just enough to secure a satisfactory spark.

The **commutator is timed** as follows:

(1) The spark control lever is advanced two notches.

(2) Number 1 piston is placed at top center between the compression and power strokes.

(3) The commutator cover is removed and the commutator housing turned so that the roller (turning anti-clockwise) is just starting to make contact with segment attached to the terminal at the left of the control rod lever.

Primary wiring is done as follows:

(1) The black wire is attached to the commutator terminal at the left of the control rod lever and to the upper terminal of the right hand coil.

(2) The red wire is connected to the commutator terminal below the one just used and the other end of this wire is connected to the upper terminal of the coil second from the right hand side of the car.

(3) The green wire is connected to the other lower terminal on the commutator (nearest center of car) and to the coil at the left hand side of the car.

(4) The blue wire is connected to the upper commutator terminal nearest the center of the car and to the coil second from the left hand side of the car.

The **firing order** of the Ford engine is 1-2-4-3.

Spark plug wires are placed as follows:
From number 1 cylinder to the right hand coil.
From number 2 cylinder to the coil second from the right.
From number 3 cylinder to the coil second from the left.
From number 4 cylinder to the coil at the left side of the car.

The **most common troubles** with the Ford ignition system are:

Vibrator contacts worn, dirty, sticking or pitted.
Vibrator spring tension too light or too strong.
Loose terminals on the back of the coil box.
Coil burned out.
Condenser disconnected (flashing at contacts) or condenser shorted (no spark at contacts).
Dirt on lower end of flywheel terminal for magneto.
Magnets weak (voltage below 11 or 12 at 20 miles an hour).
Commutator fibre ring or segments rough, grooved, pitted or wavy (replace the shell).
Commutator roller sticking, worn, loose on pin, or operating with too little spring tension.
Roller arm sticking or loose on end of cam shaft.
Grease or oil too heavy in commutator.

Troubles that occur in other parts of the Ford ignition system are located and remedied in the same manner that would be used with any other type of ignition.

The parts of the Ford system that are not included in other equipments include the magneto, the commutator or timer, and the vibrators on the coils.

Those that are different in form or appearance, but the same in principle and operation, include the coils and the condensers carried in the coil cases.

Parts that are identical and which require identical treatment include the primary and secondary wiring, also the spark plugs.

In handling troubles in the parts that are identical or that are the same in operation and principle, the information in Chapter IX should be referred to. The instructions given under the various headings covering these parts of the ignition system may be followed for the Ford equipment as well as for that specifically referred to.

CHAPTER VII

MAGNETO IGNITION

The magneto as used for ignition purposes is a simple form of dynamo having its fields formed by permanent magnets and producing an alternating current of comparatively low voltage which is changed to a high tension current by means of an induction or transformer coil carried either in the magneto or as a separate unit.

The principle upon which a magneto of the armature type generates current may be understood by reference to Figure 112. The parts shown at A include the horseshoe shaped permanent magnet M to whose extremities are attached the extensions P-P called pole pieces. The inner faces of these pole pieces are curved and between them rotates the iron core B on the magneto drive shaft. On the core is carried a coil of wire C and it is in this wire that the current flow is induced. The coil and its core are parts of the magneto's armature.

With the armature in the position shown at A in the illustration the magnetic lines of force from the magnet poles flow from the positive to the negative side, taking the path indicated by the arrows through the center of the coil. As the magneto shaft is rotated, the core and coil finally assume the position shown at B. The lines of force still flow through the core, but because of the lessened surface presented

to the face of the pole pieces, the flow has become smaller. Further rotation brings the parts to the position shown at C. Between B and C, the flow of magnetism through the coil stopped and again commenced, but now in the opposite direction through the core and the coil of wire. Between these last two

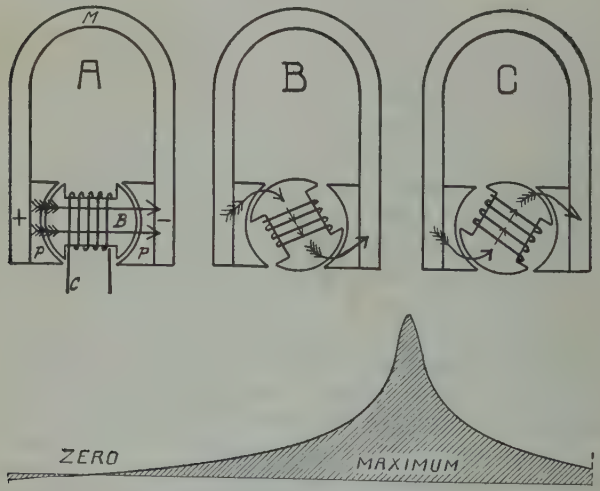


Figure 112.—Principle of Current Generation in Magneto Armature. Top: Armature Positions. Bottom: Corresponding Rise and Fall of Voltage.

points there has been an abrupt change in the intensity of magnetism acting on the coil, in fact a complete reversal has taken place. At the end of a half revolution a second reversal takes place as the core once more assumes a midway position between the pole pieces and for each complete revolution of the armature there are two abrupt changes of magnetic flow through the core and coil. The rise and fall of

the voltage is shown by the curve in the lower part of the illustration.

It was explained in Part I why it is that a change of magnetism through the core of a coil would produce a flow of current through the coil. It will be seen as a result of this fact that there will be two separate flows or impulses induced in the coil for each full turn of the armature of the magneto. One of these impulses is positive and the other negative in its direction of flow through the coil and connections, but for ignition purposes both are of equal value and each is used to produce an ignition spark or series of sparks, depending on the method employed in the remainder of the equipment.

The action of the magneto is often explained according to the rate at which magnetic lines of force are cut by the wires of the coil, or by the rate at which the magnetic lines of force are traveling relative to the coil wires. This method of explanation is the same in effect as the one just given as will be seen from reference to Figure 113. In the position shown at A, which corresponds to A in the preceding Figure, the lines of force pass through the coil as shown by the arrows and are cut through by the coil wires at the least rate of any point in the revolution. It is at this point that the current value is least as will be realized from the preceding explanation for the reason that this position is just half way between the current impulses.

Again referring to Figure 113 and position shown at B, it will be seen that the wires of the coil are cutting directly across the magnetic lines of force and therefore that the greatest possible number of lines are being cut in a given time. It is in this position,

corresponding to the point between B and C of the preceding figure that the current flow is greatest.

TYPES OF MAGNETOS

Two forms of construction are used in the manufacture of magnetos one of which, called the armature type, has just been explained and the other,

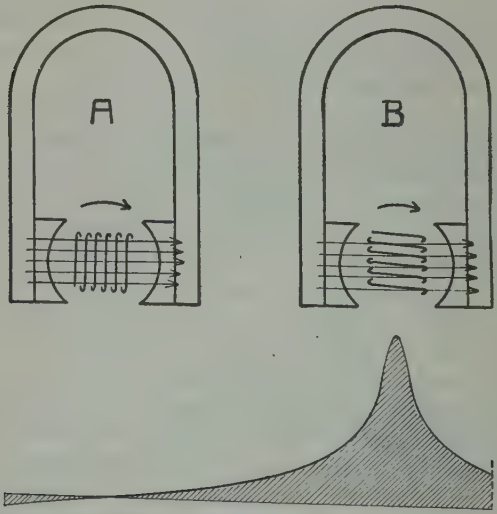


Figure 113.—Magneto Armature Coil Cutting Lines of Force in Field. Top: Armature Positions. Bottom: Change of Voltage.

called the inductor type, is explained in following pages.

Transformer Coil Magneto. — This construction includes an armature having a single winding of rather heavy wire in which is generated a current of low voltage which is sent through the primary cir-

cuit. A transformer coil is carried as a separate unit and to this coil the primary current from the magneto is led, where it produces a current of high voltage passing through the high tension or secondary circuit and to the spark plugs.

The circuits of a typical transformer coil magneto, the Remy Models P and 32, are shown in Figure 114. It will be seen that one end of the armature winding or coil is grounded to the core and from this point

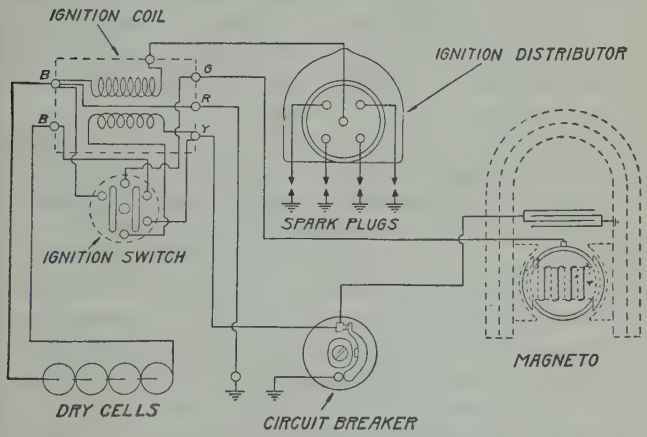


Figure 114.—Wiring of Typical Transformer Coil Magneto (Remy, Models "P" and "32").

the ground circuit is complete to the metal parts of the engine. The other end of the primary winding terminates in a brass ring on which rides a brush. The current flows to the ring, into the brush and through the wire shown, to the terminal G of the coil unit. From this terminal the current passes to the switch, which is in this case mounted on the coil

box. From the switch the current passes through the primary winding of the coil (shown near the bottom of the coil case) and then from the coil unit terminal Y to the circuit breaker. With the breaker contacts closed as shown the current passes through them and to the metal of the magneto, going through this ground connection back to the armature and the grounded end of the winding. This completes the primary circuit.

It will be noted that the condenser, in this case mounted in the magneto, is connected between one of the breaker contacts and the ground so that it is in effect placed across the breaker contacts in the usual manner.

A second primary circuit using the dry cells as its source of current is also shown. The ground connection for one side of the dry cell circuit is obtained through the line to the coil terminal B, through the coil box to the terminal R and from there to the ground. The other side of the battery is connected through the second terminal B to the switch and through the switch to the primary winding of the coil. From this winding the current flows by way of the terminal Y to the circuit breaker and is grounded through the breaker.

While the Remy instruments just described illustrate the application of the transformer coil type of construction, it is of course possible to introduce many variations in the details and the disposition of the several parts. The condenser may be carried in the magneto, or is quite often found in the coil unit. The switch may be attached to the coil or may be a separate unit, such a separation making additional wiring connections necessary. A safety spark gap

is generally arranged at some point on the coil, although it may be found in the magneto itself.

In a general way the wiring connections between the magneto and coil are the same for all transformer coil instruments in that there are three primary wires and one secondary, the secondary leading from one end of the high tension winding in the coil to the terminal connecting with the distributor rotor on the magneto. One primary wire connects the coil and magneto armature primaries, another the coil primary and breaker, and the third provides a ground for the coil primary and secondary.

The transformer coil type of magneto ignition provides two distinct sources of current, one the magneto armature and the other the battery, but all the remaining parts of the system, including breaker, distributor, coil, plugs and secondary wiring are the same for either the battery or magneto. The magneto armature carries a single winding which generates a low tension current and this current is carried to a transformer, or induction coil located at some point on the car outside of the magneto. From the high tension winding of the coil the secondary current is carried to the distributor on the magneto and from thence passes to the spark plugs. With the battery in use, its low voltage current is led to the primary winding of the same coil and the high tension circuits are the same as for magneto ignition. The breaker mechanism is included in the primary circuit with either source of current.

True High Tension Magnetos.—The type of magneto known as the true high tension does not utilize a separate transformer coil, but carries a secondary winding on the magneto armature together with the

primary winding. The primary armature winding then acts as the primary of the combination which is, in effect, a transformer coil, and produces changes of magnetism in the common core, which changes induce the high voltage impulses in the fine wire secondary winding. The difference between the two armatures is shown in Figure 115 in which the upper illustration shows the transformer coil type with the

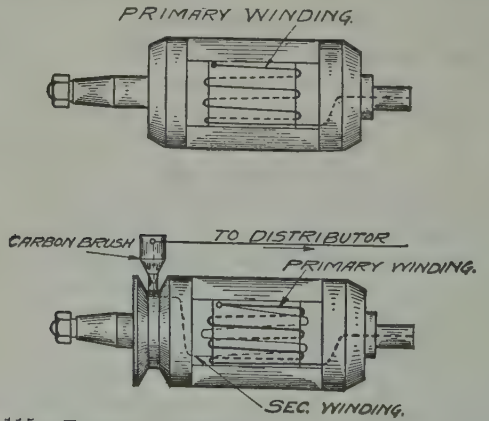


Figure 115.—Types of Rotating Armatures of Magnetos. Top: Transformer Coil Type. Bottom: True High Tension Type (Remy Electric Company).

single primary coil on the armature core, while the lower illustration shows the method of placing the two windings on the same core. One end of the secondary winding is grounded through the same ground that serves the primary winding and the other end of the secondray attaches to a conducting ring on which a carbon brush makes contact while the armature revolves. The high tension current passes

through this ring and brush to the distributor. The high tension DU4 Bosch connections are shown at the top of Figure 116. The secondary grounds through the primary, the primary connects to one breaker contact and grounds through the other contact. The

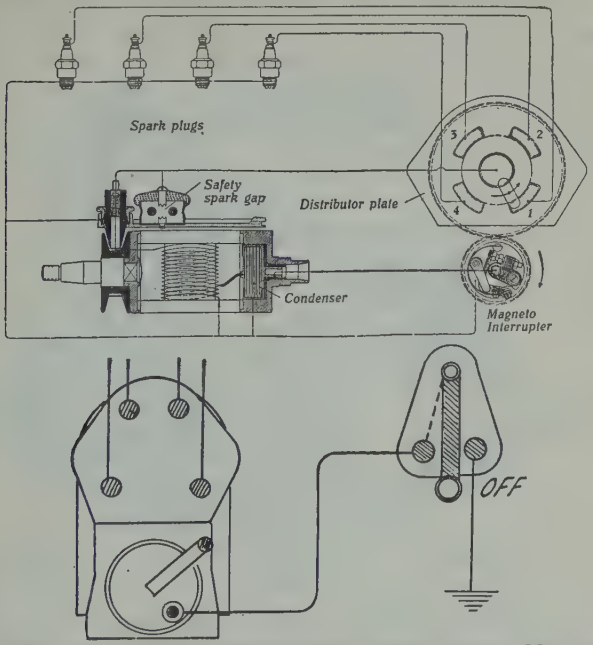


Figure 116.—Top—Circuits of Bosch High Tension Magneto. Bottom—Grounding Switch for High Tension Magneto.

condenser is in one end of the armature. The secondary leads to the collector ring and brush and the distributor. As at the bottom of Figure 116, such a magneto requires but five wires for a four-cylinder engine, four going to the plugs and the fifth from

the breaker to a switch through which the primary current may be grounded when it is desired to stop the production of sparks in the plugs. Any high tension instrument requires one line to each spark plug and one additional line for the switch.

The constructional details of a typical high tension magneto (Simms) are shown in Figure 117. This illustration shows the design of the collector ring

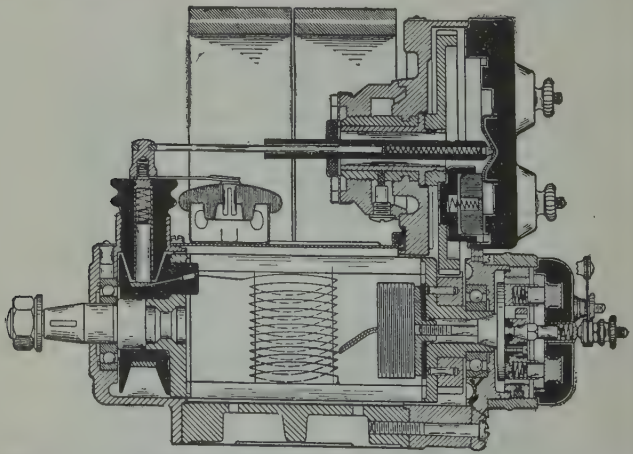


Figure 117.—Construction of True High Tension Magneto (Simms).

with its brush holder, the conductor bar between the collector brush and the center segment in the distributor, also the method of placing the safety spark gap between the collector brush upper terminal and the metal of the magneto framework.

Dual Magnetos.—The word dual is somewhat confused in its application to ignition apparatus because of the fact that those types here described as trans-

former coil machines are often called dual magnetos. We will, however, take the more generally accepted meaning and define a dual magneto as a high tension instrument having two separate circuit breakers and a separate transformer coil, one of the breakers being used for the magneto primary current, while the other is used only with the current from an auxiliary battery and in connection with the transformer coil. The separate coil is not used with the magneto primary current, this being unnecessary because the magneto armature carries two windings and generates its own secondary current.

In the transformer coil magneto both battery and magneto primary currents are handled through the one breaker, one coil and one set of primary wires, also through the one distributor and secondary system. In the dual magneto the only parts common to both sources of current are the distributor, the secondary wires to the spark plugs and the plugs themselves. The primary circuits are separate, as are the breakers and coils. A more extended description of this type will be found in Chapter VIII

Duplex Magneto.—The Bosch Magneto Company has manufactured a type of ignition styled "duplex" which combines a battery circuit with any of their high tension machines. The system includes the standard magneto and in addition, a battery and a small outside coil which are used in conjunction with the magneto. The battery side is not intended for use as a separate ignition system but only as an auxiliary to the magneto in starting.

With the battery in use the primary winding on the magneto armature is included in the battery circuit, as is also the coil, and the battery current adds

its strength to that of the magneto which at very low cranking speeds is not sufficient to produce a spark. As the magneto produces an alternating current which changes its direction of flow every half revolution of the armature, it is necessary that the battery current likewise be made to change its flow every half revolution and for this purpose a small two part commutator is carried inside the breaker housing. A change in direction of the magneto current is accompanied by a corresponding change in the flow of the battery current. As soon as the engine starts on its own power the magneto current is stronger than that of the battery and the necessity for the battery flow ceases. There is no noticeable difference in operation whether or not the battery is then in use.

The breaker housing cover consists of a fibre disc held in proper position by a key and keyway. The inner surface of the disc carries two metallic segments, each connected to a terminal on the cover, and the breaker is provided with two brushes which travel over the two segments when the armature rotates. This construction provides for reversal of the battery current. The coil unit contains a simple primary coil and the parts forming the switch. The connections for this system are shown in Figure 118.

Inductor Magnetos.—In the magnetos so far described the coils of wire in which current is generated by the magnetic lines of force have been carried by a revolving armature in such a way that the intensity and direction of the magnetic flow changes during rotation, thus producing the electrical flow. There is another type of instrument used in large

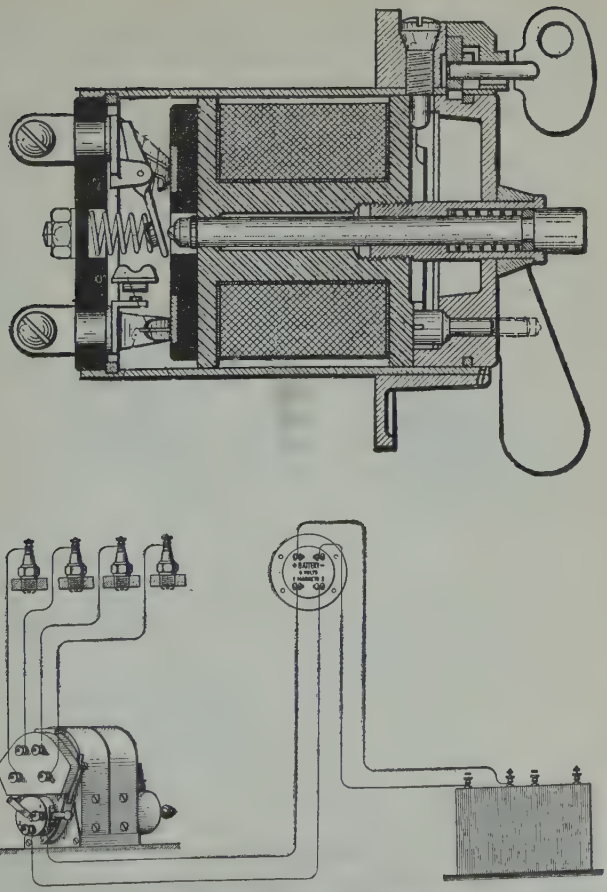


Figure 118.—Duplex Ignition System. Top: Coil and Switch. Bottom: Wiring. (Bosch.)

numbers with which the coils of wire remain stationary and with which the change in magnetic flow is secured by means of a revolving magnetic part called an inductor.

The action of the inductor may be explained by reference to Figure 119. The magnets M are of the

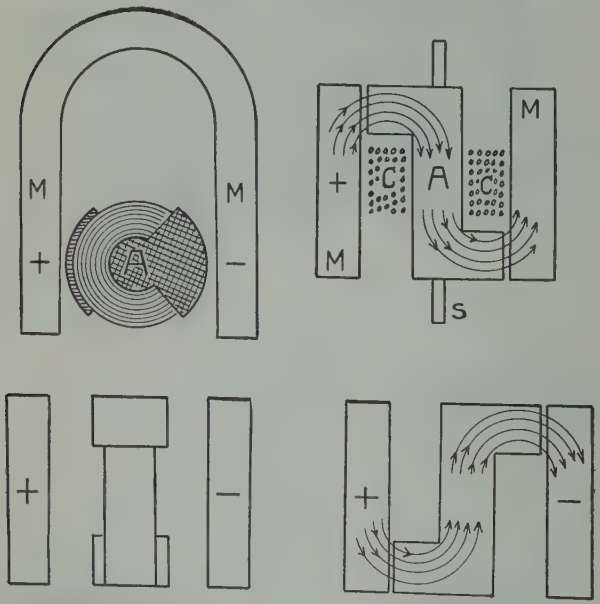


Figure 119.—Principle of the Inductor Magneto.

U-shaped type and have their positive and negative poles on opposite sides of the rotating member or inductor A which is carried on the driving shaft S. The inductor consists of a central cylindrical portion having extension pieces at each end, the piece at one

end extending in one direction and that at the other extending the opposite direction away from the shaft. The inductor rotating member is made of laminated iron. Wound around the center of the cylindrical part of the inductor is the stationary coil C in which the current flow is induced.

With the magneto parts in the position shown at the upper right in Figure 119, the flow of magnetism is from the positive to the negative magnet pole and passes downward through the coil winding. At the end of a quarter turn, in the lower left position, the inductor is in such a position that its extensions are midway between the magnet poles and the flow of lines of force has stopped and is ready to reverse. In the lower right diagram, one half revolution from the positive just above, the flow of magnetism through the center of the coil is again taking place, but now the lines of force pass upward or in the reverse direction from the first case. At the instant the magnetism changes, a powerful voltage is generated in the coil, just as with a wound armature machine. Continued rotation of the driving shaft and the inductor causes continued changes in the direction and intensity of the lines of force with resulting impulses of current flow in the coil winding.

STARTER COILS

A large number of engines are fitted with a single system of ignition provided for by a true high tension magneto without an auxiliary battery system for starting. Because of the circumstances existing, such as poor grade of fuel, size of the engine or conditions of operation, it is sometimes difficult to crank the engine with sufficient speed to produce a spark hot

enough to ignite the mixture. To overcome this difficulty, means have been developed for attaching

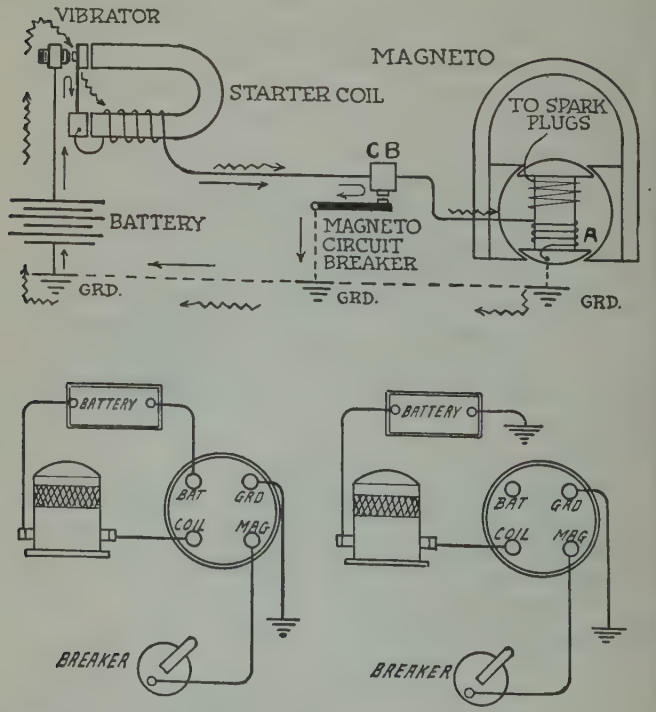


Figure 120.—Top—Circuits and Operation of the Pfanstiehl Starter Coil on Magneto. Bottom—External Wiring of the Bosch Duplex Magneto System.

auxiliary vibrating coils and battery sets to these magnetos, these coils and batteries being used in connection with the magneto breaker and distributor to

provide means for easy starting. These systems bear some similarity to the duplex type just described, with the exception that a special breaker construction is not required.

The principle of operation of a starter coil may be understood by reference to the top of Figure 120, showing the circuit of the Pfanstiehl unit. Following the straight arrows, the current passes from the battery to the vibrator and through the contacts which are normally held together by the spring. From the contacts the current passes through the coil and around the core, thus magnetizing the core and attracting the vibrator. This attraction causes the contacts to separate, stopping the flow of current until the spring again closes the contacts after the magnetism has died out. This vibrating action continues as long as the current flows. From the starter coil winding the current passes to the magneto breaker and through the closed breaker contacts to the ground, thence returning to the battery and completing the circuit. Should the magneto breaker contacts be open when the starter coil switch is closed, they will be closed as soon as a part of a revolution takes place in cranking, at which time the above described action will commence.

As soon as the cranking operation opens the magneto breaker contacts, the battery current can no longer flow to ground through them, and it then passes from the insulated breaker contact to the primary winding of the magneto armature. This pulsating current through the armature winding induces a current of high voltage in the secondary winding, one impulse being given for each opening of the starter coil vibrator and one spark produced

at the plug of the cylinder ready to fire. This stream of sparks takes place as long as the magneto circuit

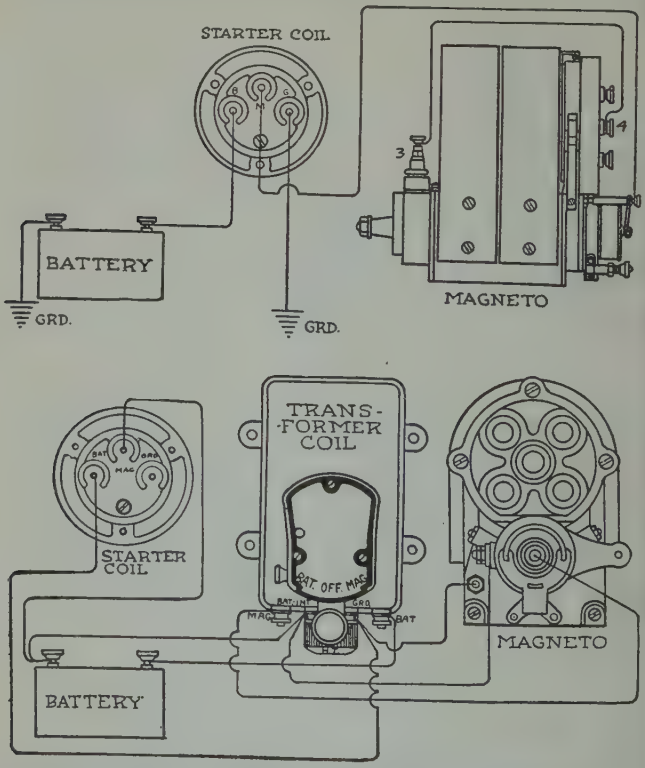


Figure 121.—Wiring of Starter Coils with True High Tension Magneto at Top and Transformer Coil at Bottom.

breaker contacts remain open, then ceases as they close, and again takes place when the contacts reopen for the next cylinder to fire.

The connections of the Pfanstiehl coils to a high tension magneto, also to one of the transformer coil type are shown in Figure 121. Connections of the Bosch vibrating duplex system, operating on similar principles, are shown in Figure 120, the left hand diagram showing an insulated return and that at the right a grounded battery.

TWO SPARK IGNITION

Certain advantages have been found in providing two simultaneous sparks at two separate points in the combustion space rather than the single spark generally utilized. Types of magnetos having distributors designed to accommodate two plugs in each cylinder are built and called two spark machines. Wiring for one such Bosch instrument is shown in Figure 122. The difference between this type and the usual form is in the secondary circuit only, neither end of the high tension winding being grounded in the two spark instrument. The high tension current induced in the secondary winding flows to one of the distributors, or to one of the halves of the single distributor, depending on the construction, and from there passes to the spark plug connected with this distributor. Entering the plug and passing across the gap, the current flows to the metal ground of the engine and through this metal to the shell of the second spark plug in the same cylinder. After passing across the gap in this second plug the high tension current flows through the spark plug wire back to the second distributor to whose rotor is connected the other end of the high tension winding, thus completing the circuit between the winding and the two plugs. No change is required in the breaker

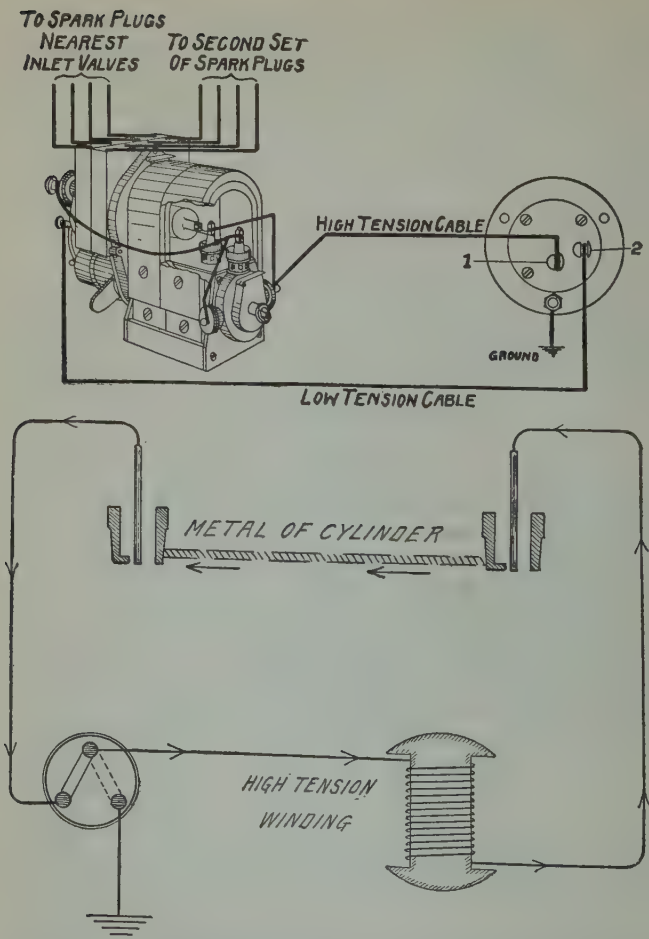


Figure 122.—Two Spark Ignition. Top: Wiring of Bosch Independent Magneto System. Bottom: Path of Current in High Tension Circuit.

or in any of the parts of the primary circuit. A schematic diagram of the high tension circuit is shown at the bottom of Figure 122.

The success of two spark ignition is largely dependent on the location of the two spark plugs with reference to each other. If they are close together, as for instance in the adjoining valve caps of an L head engine, there will be little if any difference in operation on one set of plugs or on both, for in either case the flame must travel from one side of the cylin-

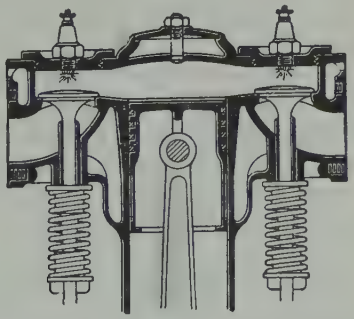


Figure 123.—Spark Plug Location for Two Point Ignition (Bosch Magneto Company).

der to the other. If the plugs are located at widely separated points, as for instance on the opposite sides of the cylinder of a T head engine as in Figure 123, the difference will be marked because the flame from either side must travel only half the distance across the cylinder before complete ignition results.

With ordinary types of ignition, and to a lesser degree with the two spark type, the time required for travel of the flame through the mixture has made it necessary to cause the spark before the piston

reaches upper dead center. This ignition advance ranges between 15 and 45 degrees and in some cases even more than 45 degrees is found necessary.

It is then obvious that if ignition is started by two sparks occurring simultaneously at two points in the combustion space, the time required for complete ignition of the mixture will be reduced. With properly designed two point ignition an increase of power amounting to about 17 percent has been secured.

The explanation given by the Bosch Magneto Company of the reasons for this increase in power or efficiency is as follows: The advance required with single point ignition entails a loss of efficiency, because, in the first place, the combustion space is not of a minimum volume when pressure is produced; and, in the second place, because of the heat loss that will result from the long contact of the burning change with an unnecessarily large cylinder wall surface. Further loss of efficiency may be traced to secondary effects, such as thrusts due to the unfavorable angle of the connecting rod, the less homogeneous quality of the mixture, etc.

MAGNETS AND POLE PIECES

The great majority of magnetos are constructed with their magnets shaped as shown at A in Figure 124, this being the U shaped magnet, although often called a horseshoe magnet. Two, four or six of these magnets are used, depending on the type, size and make of instrument. If two magnets are used, they are placed side by side with both negative poles on one side of the armature and both positives on the other. Some machines are made with two more

magnets, superimposed on the first two, still, of course, with all the like poles on one side. In some cases six magnets are used, three side by side and three more outside of the first set.

A few variations in magnet form have been introduced by various makers from time to time, two of which are shown in the illustration, the Heinze type at B and the Mea cylindrical or bell shaped magnet at C. The Heinze magnet is formed from a round bar bent into shape and machined at the lower ends. The Mea bell magnet is adopted as a part of the Mea magneto's design which maintains the same relative

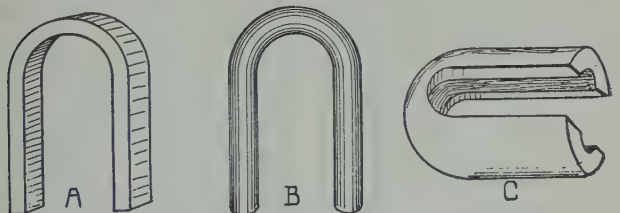


Figure 124.—Forms of Field Magnets. Left: "U" Shape. Center: Heinze Type. Right: Mea Cylindrical Magnets.

position between the armature and the magnetic field regardless of the amount of advance and retard. The Mea armature is carried longitudinally in the space within the magnet and the entire structure; magnet, pole pieces and armature, is rocked on the longitudinal axis in advancing the time of sparking.

Pole Pieces.—It is desirable, and in fact necessary, that the air space between the poles of the magnets and the iron of the armature core be as small as possible because it is with difficulty that the magnetic lines of force travel through any great distance in the air, or outside of iron and steel through any other

substance. To reduce this space the polar extremities of the magnets are fitted with pieces of iron called pole pieces, one side of these pieces being securely held against the surface of the magnet's poles, while the other side is shaped to form a recess within which the armature revolves and which is called the armature tunnel.

The application of the ordinary form of pole pieces and the position of the armature core in the tunnel is shown in Figure 125. It has been explained in the foregoing portions of this chapter that the most powerful flow of current is secured at the

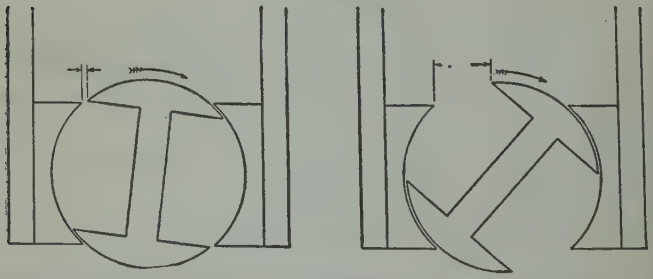


Figure 125.—Pole Piece Construction and Armature Position for Advanced (left) and Retarded (right) Spark.

instant the flow of magnetic lines of force reverses in the core of the armature, this being the position shown at the left in the illustration just as the rear edge of the armature core leaves the edge of the pole piece, the gap at this point being indicated in the drawing. It is at this time, and with the parts in this position, that the spark will be most powerful and this position corresponds to full advance on the magneto timing device.

If the spark is retarded it will occur later in the stroke and the magneto armature, being driven positively from the engine, will have traveled a considerable distance from the point shown at the left. The position of the armature core with reference to the pole pieces with the spark fully retarded will be somewhere between the point of greatest current flow and the point shown at the right of the figure. in which the magneto flow has again been established, but in which the value of the current is much reduced. It is for this reason that the spark obtained from a magneto of this type with the spark retarded is weaker than at a more advanced position and it is also for this reason that it is generally necessary to advance the timing lever from one half to two-thirds of its travel while the engine is being cranked.

To overcome this condition and to provide a spark of more nearly uniform value over the entire range of timing, some makers of ignition apparatus have adopted pole pieces of special forms which are designed to distribute over a greater range the time during which a powerful spark is secured. One of these special forms is shown in Figure 126, this being the type used on some models of Eisemann magnetos. The most extended portion of the pole pieces is opposite the center of the armature winding and the flow of magnetic lines of force is drawn from the extremities of the pole pieces toward the center of the core, theoretically sending a greater number of lines of force through the armature core and coil.

Another special form of pole piece is shown in Figure 127, this being the Simms type which would tend to continue the flow of lines of force between the position shown in full lines and that shown in

dotted lines, that is, over the entire range from full advance to full retard. With the breaker opening at the fully retarded position the gap between the edge of the armature core and the edge of the pole piece is one millimeter, while with the breaker opening in the fully advanced position the gap between armature core and the second edge of the pole piece is likewise one millimeter.

With pole pieces of the ordinary form, the voltage

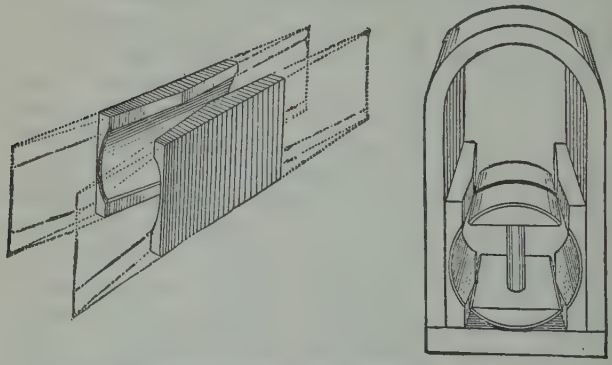


Figure 126.—Extended Pole Pieces (Eisemann).

in the primary winding of the armature rises somewhat abruptly to a peak, as shown by the curves in the lower part of Figures 112 and 113. Before this peak is reached, the pressure is comparatively low; and likewise, after the maximum point has been passed, the pressure becomes rapidly less. In order to produce a hot spark, it is necessary that the breaker open very nearly at the instant that the greatest pressure occurs.

With the various forms of extended pole pieces, the

effect is to flatten the top of the curve; the voltage then never rises quite as high as with the plain pole piece construction, but does maintain its greatest pressure during a considerable number of degrees of armature rotation. If the breaker contacts separate at any point along this flattened top of the voltage curve, a hot spark will then be produced.

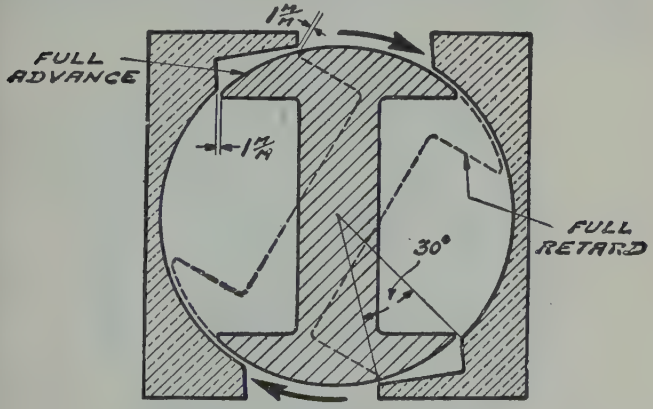


Figure 127.—Extended Pole Pieces and Position of Armature When Spark is Advanced (full lines) and Retarded (dotted lines).

MAGNETO BREAKERS AND DISTRIBUTORS

Magneto Circuit Breakers.—The general construction and principles of operation of magneto breakers do not differ form those described for battery systems in Chapter Two. The magneto breaker is carried at one end of the armature shaft and is operated at the same speed as the armature shaft. With the exception of one or two makes but little used, the magnetos all produce two current impulses and two

sparks for each full revolution of their armature. Therefore, since the breaker must open once for each spark, it must open twice during each revolution of the armature. It is for this reason that magneto breakers are fitted with two point cams for all engines having four or more cylinders rather than with a cam having a number of lobes corresponding to the number of cylinders to be fired as with battery systems.

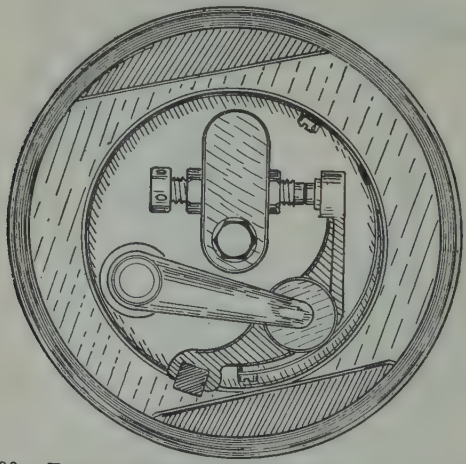


Figure 128.—Typical Magneto Breaker with Stationary Cams.

While the battery types of breakers are so constructed that the cam rotates and the arm and contacts remain still, a large number of magneto breakers are so made that the cams are carried in the breaker housing and remain stationary while the arm and contacts are mounted on a base plate carried by the end of the armature shaft and which accordingly revolves.

A breaker of this type is shown in Figure 128. The two cams may be seen around the inside of a housing which remains stationary except for the small movement required in advance and retard of the spark. The other parts shown, including the fixed contact on its adjusting screw together with the arm carrying the moving contact, are mounted on a base which is rotated by the magneto shaft. The breaker arm is pivoted near its center and under-

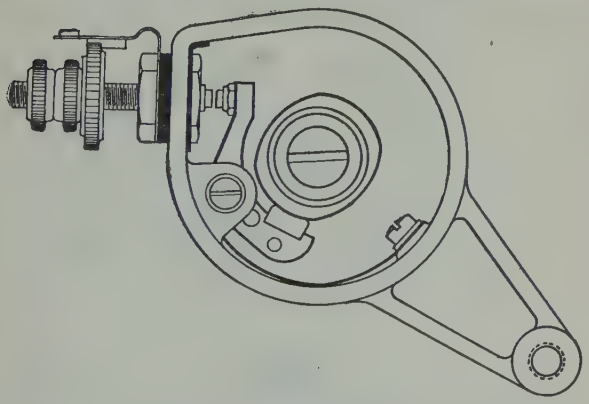


Figure 129.—Magneto Breaker with Rotating Cam (Remy, Models "RD" and "RL").

neath the small flat retaining spring shown. At one end is the contact point and at the other a fibre block which, during rotation of the base, strikes alternately first one cam and then the other. This action opens the contacts twice during each revolution of the armature.

A form of breaker used with magnetos and having the revolving cam is shown in Figure 129. It will

be seen that, but for the cam having only two lobes, the construction is practically the same as the battery types.

Distributor Construction.—The magneto distributor is generally located just above the breaker mechanism and is driven by two gears at one-half, three-quarters or full armature shaft speed depending on the number of cylinders. One gear is on the armature shaft and the other carries the rotor of the

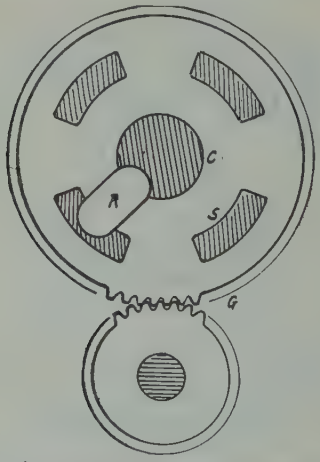


Figure 130.—Typical Construction for Magneto Distributor.

distributor, the distributor gear being larger in size than the armature shaft gear. These parts are shown in Figure 130. High tension current from the secondary winding of the coil or the armature is brought to the central metallic plate C which is carried in the cover of the distributor. The rotor R is carried by the large gear and makes electrical connection

between the central plate and the segments S, of which there is one for each cylinder to be fired.

Another form of distributor is shown in Figure 131, the distributor cover carrying the brushes which take the place of the segments in the preceding figure. The cover is illustrated at the left and the rotor member which is carried by the large gear is illustrated at the right. This form is used on a true high tension magneto (Eisemann) and it carries the collector brush in the lower part of the distributor cover. This brush rides on the collector ring and takes the

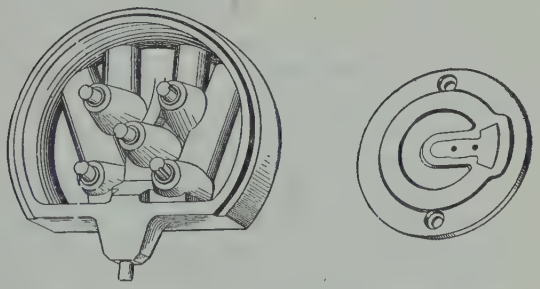


Figure 131.—Magneto Distributor of Wipe Contact Type (Eisemann).

high tension current from the armature to the central brush of the distributor cover, from which it enters the rotor segment and is carried in turn to the brushes connected with the spark plug wires. While the two forms of distributors just shown are both of the wipe contact type, many magneto distributors are made of jump spark construction in which the secondary current passes from the rotor across a minute gap to a series of pins or segments set into the insulating material of the cover.

Distributor Setting.—It will be noted that in the construction of all distributors either the rotor or the segments with which it makes contact provide for a considerable length of contact. This is necessary because the time during the revolution of the armature shaft and the distributor rotor at which the high tension impulse passes through the distributor varies with the degree of spark advance being employed. If the rotor just matched the segment the spark current would pass successfully with the timing device for the breaker in only one position, but, should the point of sparking and breaker opening be changed, then the spark current would pass either earlier or later and the distributor rotor would not be in full contact with the segment for the cylinder to be fired.

On most magnetos it will be found that the small gear on the armature shaft carries a mark near one of the teeth and on the distributor gear will be found two marks at different points, either of which may be made to register with the one on the small gear. One of these marks on the distributor gear will be marked L or "Left," while the other will be marked R or "Right." If the magneto is designed for right hand or clockwise rotation (when looked at from the driven end), then the distributor gear mark R should be registered with the mark on the armature shaft gear, while if the machine is for left hand or anti-clockwise rotation, looked at in the same way, then the mark L should be registered.

With these markings properly set with reference to the rotation of the magneto it will be found that, with the timing lever fully advanced, the distributor rotor is just coming into contact with one of the

segments when the breaker contacts start to separate. If this relation is not found to exist, then the setting of the gears should be changed so that it is made correct. In Figure 132 are shown three relations of the rotor and segments, two of which are wrong (A and B) while the third, C, is correct. If the proper relation is not secured between these parts severe

Figure 132.—Relation of Rotor and Stationary Contacts in Magneto Distributor. A and B: Incorrect Setting. C: Correct Setting.

burning and pitting will result and the effectiveness of the spark will be seriously impaired.

The high tension circuits of magnetos are protected by a safety spark gap which may be found located in the distributor, at the collector ring, underneath the arch of the magnets or on the coil, depending on the type and make of instrument considered.

The breaker housing in which are carried the breaker cams is so arranged that it may be rotated 30 to 40 degrees with respect to the armature shaft. Movement of this housing in the direction the armature rotates retards, while moving it in the opposite direction advances the spark.

MAGNETO TIMING

The principles and general procedure of ignition timing, as described in Chapter IV, apply in a gen-

eral way to the timing of magnetos. Details of magneto work will now be described.

In the first paragraphs of this chapter and in Figures 112 and 113 it was explained that the time of greatest current intensity occurs just as the magnetic flow reverses through the core of the coil. This position for Bosch magnetos is shown for clockwise

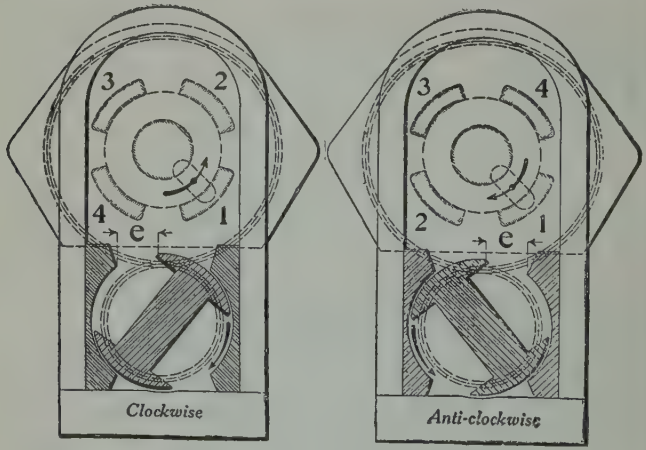


Figure 133.—Position of Armature in Relation to Opening of Breaker Contacts.

and anti-clockwise rotation in Figure 133 at dimension "e." Four-cylinder machines take about ½ inch and six-cylinder types about ⅝ inch or slightly more for the opening at this point.

The magneto should be placed on its bracket and secured in place, the driving coupling, however, being left free from the shaft. The engine should then be slowly cranked until the piston of number one cylinder is at top dead center following the compression

stroke. With the engine in this position the armature of the magneto should be revolved until it is in the position shown in Figure 133. With the armature held in proper position the gear or coupling should be secured. This setting places the armature and engine crankshaft in such relation to each other that the current is at its maximum when the piston is in the firing position.

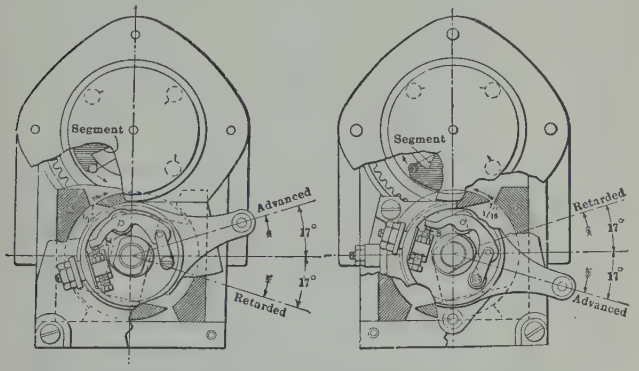


Figure 134.—Armature and Distributor Settings of Splitdorf Magneto.

The gears attached to the armature shaft and distributors are so meshed that the distributor rotor is in contact with a segment leading to the spark plug wires. The breaker cam is so placed that the contacts separate with the armature in the most effective position, and the proper relations between armature, breaker opening and distributor setting must be maintained for correct operation. The proper relation between the parts mentioned as obtained in a Splitdorf magneto is shown in Figure 134.

A commonly used method of practical timing is to slowly crank the engine until the piston of number one cylinder is at top center following compression. With the magneto in place on its support the advance and retard arm on the breaker housing should be fully retarded, that is, moved to the limit of its travel in the same direction the armature rotates. The magneto distributor plate should be removed and the cover of the breaker also removed. The magneto armature should then be rotated in the direction it is driven by the engine until the breaker contacts are just about to separate. With the armature, breaker, advance lever and piston in the positions described, the driving coupling should be secured.

While ignition timing is generally done with the breaker retarded, the same results may, of course, be obtained by timing with the parts fully advanced. The maximum advance required is generally measured in degrees of a circle on the rim of the engine flywheel. Any amount of advance or retard may be specified by mentioning the distance around the rim, either before or after top center of piston travel. By reference to Figure 135 it may be seen that the piston travel up and down, measured in inches, is not in direct proportion to the measurement in degrees around the rim of the flywheel. For the first 15 degrees of flywheel travel the piston moves but a very short distance. During the next 15 degrees the distance of piston travel is much greater, while from 30 to 45 degrees there is another increase, and so on until the 90-degree mark is reached.

In some cases the degree of advance is mentioned in fractions of an inch of piston travel, while in others it is mentioned in degrees of the circle around

the flywheel. Either of these measurements may be translated into the other by means of the simple diagram shown in Figure 136.

The relation of the piston travel to the rotation of the crankshaft depends on the stroke and the length of the connecting rod. In this diagram the relation between the crank and connecting rod length is as 1 to 4½. The vertical lines give the stroke of the engine in inches, the rotation of the crankshaft in degrees being indicated by the slanting lines and the

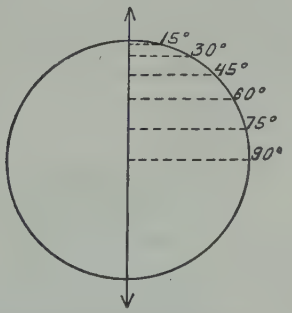


Figure 135.—Relation of Piston Travel to Degrees of the Circle.

numbers at the right. The numbers on the left and the horizontal lines indicate the piston travel in inches. As an example in the use of the diagram, to find the piston travel for an advance of 30 degrees on an engine with 6-inch stroke; the vertical line "*a*" for the desired stroke may be followed upward until it cuts the diagonal line at "*c*," indicating 30 degrees in the present case. The horizontal line "*b*" nearest this point should be followed to the left and will be seen to indicate about ½ inch, the advance in inches of piston travel corresponding to a

rotation of 30 degrees measured on the flywheel.

If the piston travel in inches and the stroke of the engine in inches are known, it is likewise possible to find the number of degrees on the flywheel corresponding to the piston travel. Taking, as an example, an engine with 4½ inch stroke in which the piston travel is found to be ⅝ inch, the intersection of the horizontal line for ⅝ inch with the vertical line for 4½ inches will be found on the diagram. From this intersection the diagonal line is seen to run up to the 40 degree mark, so this piston movement of ⅝ inch is known to represent a flywheel travel of 40 degrees either way from top dead center. This diagram is also of value in timing the valves of an engine.

MAGNETO DRIVE

Except for a few types of inductor machines all magnetos are so constructed that they deliver two sparks for each full turn of their armature shaft. Four cycle engines require one spark during each two revolutions of the crank shaft for each cylinder of the engine. A four cylinder engine will then require four sparks during two revolutions of its crank shaft, or two sparks for one revolution. A six cylinder engine will require six sparks in two revolutions and three sparks in one. An eight cylinder engine, according to the same principle, will require four sparks during each crank shaft revolution and a twelve cylinder engine will require six.

The magneto producing two sparks for each armature revolution must, therefore, be driven on a four cylinder engine at crank shaft speed because such an engine requires the two sparks produced in this

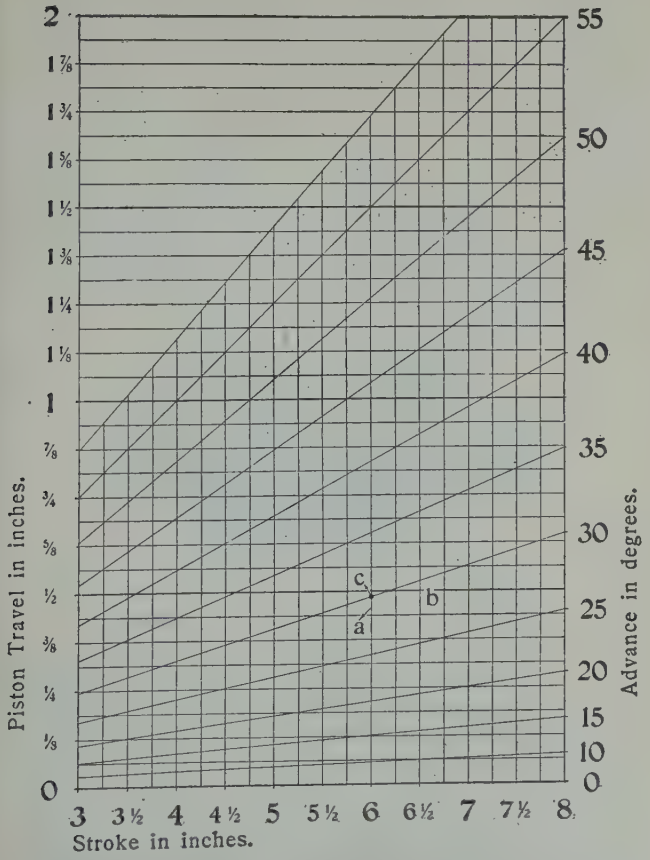


Figure 136.—Chart for Translating Piston Travel and Degrees of the Circle (Bosch Magneto Company).

one crank shaft revolution. Similarly a magneto on a six cylinder engine must be driven at 1 1/2 times crank shaft speed, on an eight cylinder engine at twice crank shaft speed, and on a twelve cylinder engine at three times crank shaft speed.

While some few magnetos are driven from the engine by means of silent chains the great majority are driven by means of gears meshing with the timing gears on either the crank shaft or cam shaft of the engine. In the latter case the magneto is mounted on a base formed as a part of the engine crank case and the armature shaft of the magneto is connected

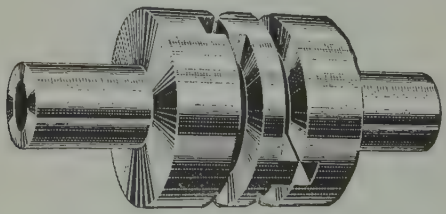


Figure 137.—Oldham Coupling.

with a shaft driven from the engine gears by some form of coupling.

One of the first used couplings, that known as the Oldham, is shown in Figure 137. This coupling consists of three parts, two metal discs having grooves which engage raised keys at right angles on the opposite faces of a center member. One of these discs is attached to the armature shaft of the magneto, while the other is connected with the driving shaft of the engine. While the Oldham coupling is preferable to a straight shaft drive it leaves much to be desired. A satisfactory magneto coupling should be flexible,

that is, it should allow for a certain amount of axial or angular displacement of the driving shaft and the magneto armature shaft. It may also be found advantageous to have the bearing provide somewhat of a cushioning effect. A magneto coupling should also be adjustable, so that a certain amount of timing may be accomplished by this means. A satisfactory coupling should have good wearing surfaces and should be easily taken apart, so that the magneto may be removed from its base without trouble. Many coup-

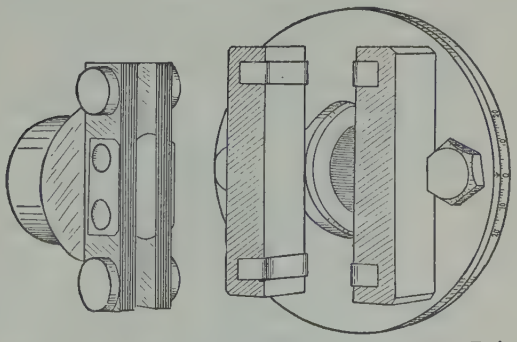


Figure 138.—Flexible Coupling for Magneto Drive (Eisemann).

lings have been developed embodying several or all of these desirable features.

A coupling made by the Eisemann Magneto Company is shown in Figure 138. The driving member carries two sets of flat steel springs at whose outer ends are mounted buttons which provide a bearing surface. When in the driving position this member is engaged between two blocks mounted upon a disc forming the second part of the coupling. This disc is composed of two plates held together by bolts

passing through slots. With these bolts loosened one of the discs may be turned with reference to the other and the timing thus changed.

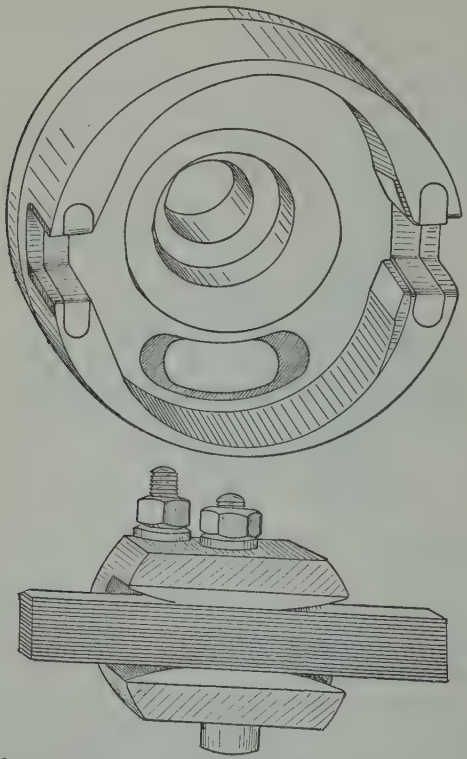


Figure 139.—Flexible Coupling for Magneto Drive (Bosch).

The parts of the Bosch coupling are shown in Figure 139. It consists of a cone-shaped piece of steel attachable to the armature shaft, terminating in

a rim having diametrically opposite fibre lined slots. To the driving shaft is secured a flange that carries a flat cross-bar consisting of a large number of fine spring steel plates or leaves. The cross-bar fits in the slots of the cone-shaped member.

This laminated cross-bar has a marked spring action and permits the two members of the coupling to have a slight relative torsional movement, which is ample to absorb the shock of the varying resistance to rotation of the magneto armature. Furthermore, the spring cross-bar has a slight bending or twisting movement sideways, permitting the two shafts to be slightly out of line. With a rigid coupling both driving shaft and magneto shaft must be in absolute alignment and the shock caused by the magneto resistance is transmitted to the driving gears.

A coupling made by the Westinghouse Electric & Manufacturing Company consists of two cup shaped steel discs having their outer edges formed into a series of fine teeth. With the discs pressed together and with the cupped portions facing each other the teeth may be engaged so that one part will drive the other. The timing may be easily changed with such a coupling and it also allows for a certain amount of misalignment.

A commonly used form of coupling is shown in Figure 140. This type consists, as in most of the others, of two discs, one attached to the magneto armature and the other to the engine driving shaft. Between the two discs is a flexible member of leather of or rubber impregnated fabric. This flexible part is attached to one of the discs at two diametrically opposite positions and to the other at two points between the first two.

A form of coupling designed to allow variation in the timing consists of two flat circular plates, each having a series of holes drilled in a circle near its outer edge. These two plates are fastened together by two bolts passing through the holes. The holes are unequally spaced, so that the distance between those at one point is greater than at another point. With the fastening bolts removed from any two pair of holes in which originally found, one of the plates may be turned a greater or less distance with reference to the other and in this new position the bolts

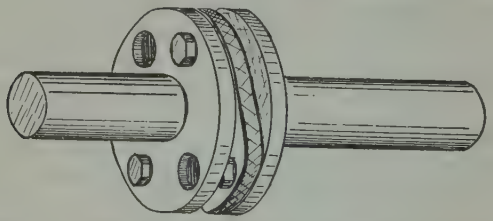


Figure 140.—Flexible Disc Type of Magneto Coupling.

may be replaced in different holes which will then be found in alignment.

STARTER COUPLINGS

Because of the fact that a magneto will not produce a spark across the plug gap at very low speeds and because engines of large size cannot readily be cranked at speeds great enough to produce a satisfactory spark, a device known as the starter coupling has been introduced.

The starter coupling, or as it is sometimes known, the impulse starter, is so constructed that during a part of each revolution of the shaft driving the mag-

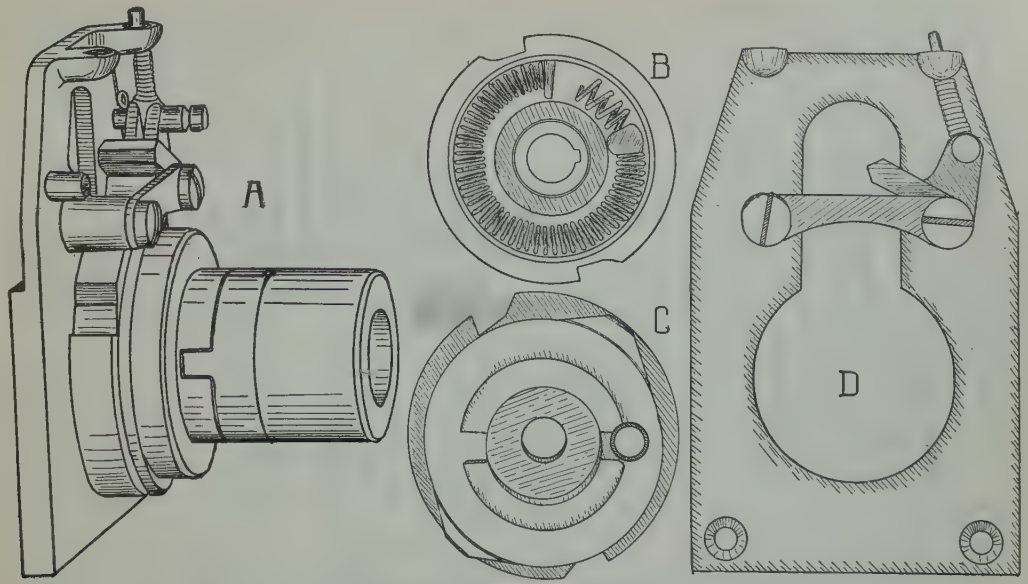


Figure 141.—Impulse Starter for Magneto Drive (Splitdorf).

neto, turning of the armature shaft is prevented by a pawl. During this time the continued rotation of the driving shaft compresses a spring which is a part of the starter coupling. Just as the engine reaches one of its firing points, the spring is released and the armature shaft is given a quick impulse and turns much faster than the driving shaft until the original relation between the two is restored. This impulse occurs during the time that the breaker points separate and the result is a hot spark regardless of the cranking speed.

The construction of one form of starter coupling (Splitdorf) is shown in Figure 141. At A is shown the coupling assembled on the magneto. At B is shown the interior of the cam member. At C is shown the exterior of the cam member and at D the end plate of the magneto with the stationary part of the coupling in place.

When the engine is to be cranked the pawl is thrown into its operating position by means of a small plunger. The pawl engages the cam portion of the coupling and prevents movement of the armature shaft. The cam member continues to revolve and the long coiled spring is compressed. The driven member of the coupling continues to rotate until the cam with which it is integral reaches the pawl. This cam forces the pawl out of the notch, the compressed spring expands and the magneto armature shaft is forced forward at a speed corresponding to several hundred revolutions a minute. The short cushion spring shown at B absorbs the shock and brings the rapidly moving armature shaft to a gentle stop.

The shape of the pawl and of the notch is such

that when the engine reaches a speed of from 200 to 250 revolutions per minute the pawl is thrown outward with such force that it is caught and held in the inoperative position. In another type of Sumter coupling the impulse device is automatically thrown into and out of engagement. The action of the coupling automatically retards the spark for starting and the impulse spark is several degrees later than the normal retard position of the magneto. With the engine running normally the coupling makes no difference in the time of the spark, whether the timing lever of the magneto is advanced or retarded.

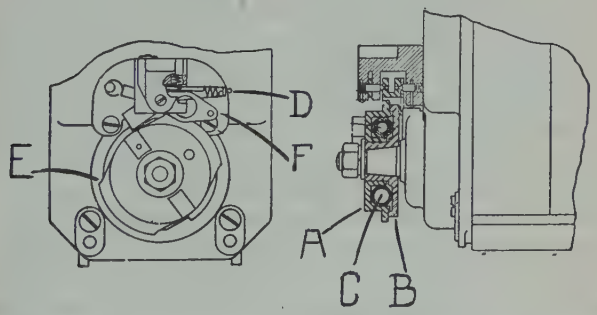


Figure 142.—Impulse Starter Operation (Teagle).

The Teagle impulse starter is illustrated in Figure 142. The action of this starter is as follows: As the engine turns over, the member A is turned around by the driving shaft and moves the member B with it through the pressure of the spring C. The member B is rigidly connected to the magneto shaft. When the notch on member B reaches the top, the pawl D drops into the notch and stops the movement of B. The member A continues to move and compresses the

spring C. When the member A has moved far enough to bring the side E against the pawl D, the pawl is forced out of the notch and the force of the compressed spring drives the member B and the attached magneto shaft forward at a high velocity giving a very intense spark. As the engine picks up speed, E forces the pawl D out so far that it is carried past dead center and remains out until pulled in by hand, preparatory to starting the engine again.

The design and proportion of the impulse starter is such that when the pawl is operating, the spark occurs on dead center, thus obviating danger of back fire. When the pawl is thrown out as the engine picks up, the spark automatically advances about 25 degrees, thus giving the most efficient operating engine condition without further attention of the operator. In starting the engine, the operator should be sure to pull the lever F upward, which automatically throws the pawl D into engagement.

The action of the Eisemann starter coupling may be understood by reference to Figure 143; in which, at the left, is shown the device when ready for cranking, and at the right when in the running position. The mechanism consists of five essential parts; a housing H which is attached to the magneto armature shaft; a driving member C which is driven from the engine; a spiral spring S which is hooked to members H and C; a floating member or trigger T; and a fixed bar B which is mounted on the base of the magneto.

When the engine is cranked, the trigger T drops by gravity, engages with the bar B, and thus temporarily prevents rotation of the housing H. As the cranking continues to turn the member C, the spring S is wound up until the cam at C strikes the wedge W.

This forces the trigger upward until it slips off the lower bar; thus releasing the housing H and allowing the tension of the spring to give the armature shaft a quick impulse during part of a turn.

It will be seen that, after the release and as shown at the right of the figure, the armature shaft is prevented from being thrown past the normal position by stops which are provided on the housing and on the outer part of member C. It will also be noted that member T is heavily overweighted on its upper

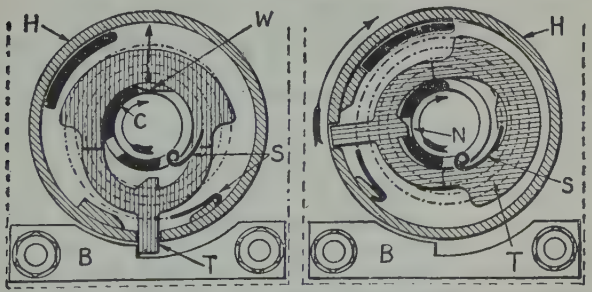


Figure 143.—Starter Coupling. Left: Starting Position. Right: Running Position. (Eisemann.)

half, so that the action of centrifugal force on this counterweight draws this member toward the center until a tooth enters the notch N on the driving member C. The trigger is held in this position as long as the engine operates, the notch giving a positive drive for the magneto, independently of the spring.

Should the starter be rendered inoperative for any reason, an emergency locking device may be engaged as follows: Turn the engine until a heavy scratch mark, to be found on the edge of the driving member C, comes to the top. Then rotate the housing H as

far as possible in the normal running direction, or until the hole for the trigger comes opposite the scratch mark. In this position the trigger should drop into its running position. The screw which fastens the small locking plate should now be loosened, the plate swung parallel to the center line of the magneto, and the screw securely tightened again. The locking plate will now prevent the trigger from engaging with the notched bar B and the starter will act as an ordinary coupling.

Oiling of this coupling is necessary only about once in two years use; and then only a light, non-gumming oil should be used. Under no circumstances should the internal mechanism be oiled with a heavy cylinder oil or packed with grease, as such a procedure would immediately put the device out of action.

MAGNETO MOUNTING

A magneto should never be mounted upon either an iron or a steel base because in this case the metal of the base would form a conducting path for the magnetic lines of force between the two poles of the field magnets. This would then form an easier path than that through the magneto armature with the result that the current generating properties of the machine would be almost, if not quite, destroyed. Satisfactory magneto bases may be made from aluminum, brass or bronze because all of these are non-magnetic.

The correct position of a magneto upon its base is generally fixed by means of dowel pins set either into the magneto or the base. The magneto is then held securely in place either by means of bolts passing

through the base and into the framework of the magneto or by means of one or more metallic strips which form clamps attached to the base and passing over the arch of the magnets.

REVIEW OF CHAPTER VII

MAGNETO IGNITION

The **greatest voltage in a magneto** is secured at the instant the lines of force reverse through the coil windings.

Revolving armature, or shuttle armature, magnetos carry their coils on a revolving member. **Inductor magnetos** have stationary coils through which the flow of magnetism is reversed by the inductor.

Transformer coil magnetos have two current sources and a separate induction coil, but use the same breaker and distributor for both sources. **True high tension** magnetos have both primary and secondary windings in the magneto and require no outside coil.

Dual magnetos use two sources of current and use the same distributor and high tension circuit for both sources. They may have either one or two breakers and may have a separate induction coil or use the magneto windings for both sources.

Some forms of dual (or duplex) magnetos send battery current through the magneto primary circuit for starting.

Starter coils provide a stream of sparks by the use of a vibrator acting on the magneto primary circuit while the breaker contacts are separated.

Two-spark ignition uses one high tension circuit with two spark plugs in series to provide two simultaneous sparks at different points in the combustion space.

Magneto breakers may have stationary cams in the housing, with revolving contacts; or they may have revolving cams with stationary contacts mounted in the housing.

Magneto distributors should be set so that the rotor is just starting to make full contact with a segment as the breaker opens at full advance.

Magneto timing (with retarded spark) is done as follows:

(1) The magneto is mounted with its coupling left free.

(2) The engine is cranked until number 1 piston is at top dead center following compression.

(3) The magneto control lever is fully retarded by moving it as far as it will go in the direction the armature runs.

(4) The magneto shaft is turned in the direction it runs until the breaker contacts just start to separate.

(5) The coupling is fastened with the parts in these positions.

Shuttle armature magneto timing (with advanced spark) may be done as follows:

(1) The magneto is mounted with the coupling left free.

(2) Number 1 piston is brought to top dead center following compression.

(3) The magneto control lever is placed at full advance by moving it to the limit of travel against the direction of armature rotation.

(4) The armature is turned in the direction it runs until the edge of the armature core has left the edge of the pole piece with a gap of 3/8 to 5/8 of an inch.

(5) The coupling is secured with parts in these positions.

Starter couplings, or impulse starters, stop rotation of the magneto shaft during part of a revolution while compressing a spring. Release of the spring at the firing point rotates the armature at high speed and produces a hot spark even at low cranking speeds.

CHAPTER VIII.

MAGNETO IGNITION SYSTEMS

DU TYPE BOSCH MAGNETOS

All Bosch instruments are of the true high tension type having both low and high tension windings on the armature and operating as complete self contained units without the addition of outside coils or other parts except the spark plugs, the plug wires and a simple grounding switch. These magnetos are usually employed as the sole source of ignition although they may be fitted in connection with an entirely independent system having its separate set of plugs.

The armature winding is composed of two sizes of wire, one size comparatively heavy and the other very fine, the heavy wire constituting the low tension or primary and the fine wire the high tension or secondary circuit. The rotation of such an armature between the poles of powerful permanent magnets induces pulsations of current in the primary winding and in this circuit is the circuit breaker. The high tension current thus generated passes to a ring at one end of the armature and is collected by a brush in contact with the ring, being then sent to the distributor to which the spark plug wires are attached. The relation of these parts to each other and the electrical connections are shown in Figure 116.

The beginning of the armature primary circuit is

in metallic contact with the armature core and the other end of this winding is connected by means of the breaker fastening screw to an insulated block on the breaker base which supports one of the contact points. The breaker arm, carrying the other contact point, is mounted on the breaker base and is connected or grounded through the metal with the armature core. The primary circuit is complete whenever the two contact points are together and is broken by the end of the breaker arm coming in contact with one of the cams carried in the breaker housing or shell.

The armature high tension circuit is a continuation of the primary, the beginning of the secondary winding being connected to the primary, while the other end of the secondary leads to the insulated ring called the slip ring which is mounted on the armature just inside the end plate at the driving end. The detailed construction of the magneto is shown in Figure 144.

The slip ring brush receives the high tension current and by means of the connecting bar underneath the arch of the magnets this current is carried to a metal contact in the center of the distributor cap or plate. From this center contact the current passes to the distributor brush which is carried by a holder mounted on the distributor gear and which consequently rotates with the gear at one-half armature speed for four-cylinder engines.

Metal segments are imbedded in the distributor plate and as the brush rotates it makes contact successively with the segments in the plate. The segments in turn are connected with terminals on the outside face of the plate and these terminals are connected by wires to the spark plugs in the several

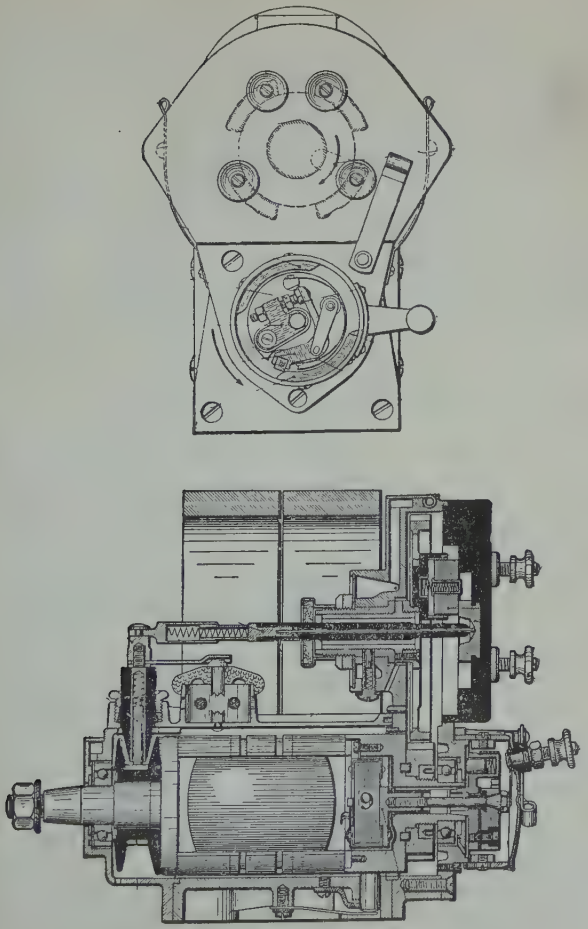


Figure 144.—Construction of True High Tension Magneto (Bosch "DU").

cylinders. The high tension current passing across the gap between the spark plug electrodes produces the ignition spark and then returns by the metal ground connections to the magneto armature core, thus completing the secondary circuit.

In order to protect the armature and other current carrying parts a safety spark gap is arranged on the dust cover above the armature. This gap consists of two small, pointed electrodes supported a short distance from each other. One electrode is set on

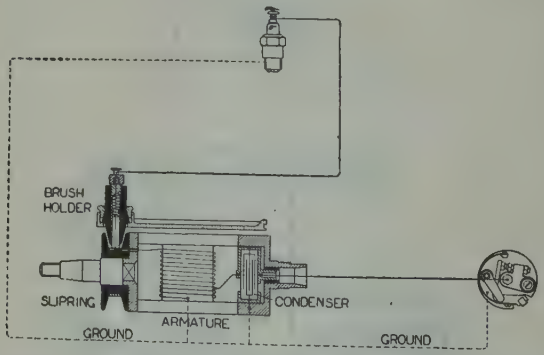


Figure 145.—Circuits of Bosch High Tension Magneto.

the dust cover itself and is enclosed by a metal housing with a wire gauze screen for the prevention of accidental fires in inflammable gas which may be present. The other electrode is set in the center of the insulating cover of the safety spark gap housing and is connected with the slip ring brush by a short spring.

An insulated grounding terminal is provided on the cover of the magneto breaker and the inner end

of this terminal, consisting of a spring with a carbon contact brush, presses against the breaker fastening screw which is connected to the primary winding. This terminal is connected to one side of the magneto switch, and the other side of this switch is grounded to some metal part of the chassis. Figure 145 shows a simplified circuit diagram without the distributor.

ZR TYPE BOSCH MAGNETOS

These magnetos differ from the DU types chiefly in being fully enclosed and water and dust tight in their housings. Among the minor improvements on the ZR magnetos is that by means of which the advance and retard lever on the breaker housing may be placed in any desired angular position and held in place by means of a screw ring.

Timing.—The method of setting or timing the ZR magnetos is peculiar to these instruments, not in the result obtained, but in the method employed, and will therefore be described. Timing is accomplished by observing the position of the distributor gear through the opening exposed by lifting the oil well cover which is on top of the instrument and just back of the distributor, also by observing a figure "1" through a small window in the distributor cover.

The first step in timing is to bring the piston of number one cylinder to top dead center following the compression stroke, then turning the flywheel backward until the piston has moved downward from ¼ to ½ inch, or, until the crank shaft and flywheel have been turned backward from 22° to 34°. The magneto armature should then be turned until the figure "1" appears through the window in the dis-

tributor plate. Now lift the oil well cover and observe the distributor gear through the round sight hole. The armature is then to be further turned until the marked distributor tooth registers with the marks on the side of the opening. With the armature and piston in these positions the drive should be connected, care being used that the relative positions are not disturbed. As with the DU instruments, the exact timing for best operation may be determined by experiment or by instructions from the manufacturers of the car, but in the majority of cases the limits given will produce satisfactory results.

BOSCH DUAL MAGNETOS

While the independent high tension magneto produces an entirely satisfactory spark, it generates a current only after the armature is in fairly rapid motion produced by cranking. The dual system provides the engine with an ignition system having a battery as the source of current in addition to the magneto and with the battery in use the engine may be started at low cranking speeds or, with some modifications, by throwing the switch or pressing a button. In the dual system both the battery and magneto make use of the same spark plugs, the same spark plug wires and the same distributor, but otherwise the two systems are distinct. The appearance of a dual breaker is shown in Figure 146.

The Bosch dual magneto is of the standard Bosch high tension type, timed by the revolving breaker as in other instruments. The parts of the breaker are carried on a base plate attached to the end of the armature shaft and rotating with this shaft. The

segments or rollers that serve as cams are carried by the breaker housing as in other types.

In addition to the parts mentioned, which are also found on the independent machines, the dual magneto is provided with a steel cam having two lobes or projections, this cam being built into the breaker base. This cam acts on a lever arm which is supported by the breaker housing, this arm being so connected in the battery circuit that it serves as

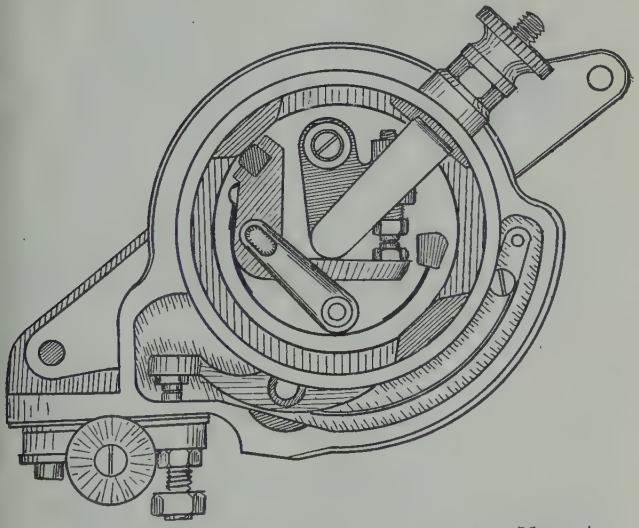


Figure 146.—Breaker of Dual High Tension Magneto (Bosch).

the arm of a breaker which interrupts the battery current through a separate coil.

It is obvious that the high tension current from the battery and from the high tension magneto should

not be led to the spark plugs at the same time and further change from the independent magneto i found in the absence of the connecting bar betwee the slip ring brush and the distributor. In place the brush is connected to the switch in the coil hous ing and another wire carries the high tension cu rent back from the switch to a central terminal o the distributor.

When running on the magneto, the high tensio current that is produced flows to the distributor b way of the switch contacts. When running on th battery, the primary circuit of the magneto i grounded through the switch and there is therefor no production of high tension current by the mag neto armature. The high tension current from th battery and coil then flows to the central termina of the distributor.

Coil and Switch.—The coil is carried within a cyl indrical housing on the front of which is the switc handle and lock and on the engine end the terminal for the magneto and battery connections. In operat ing the switch the entire coil is rotated within th housing. The inner side of the stationary switc plate is provided with spring contacts that registe with contact plates attached to the end of the co through which the various connections are obtained

In order to render starting easier and to make i possible to start on the spark a vibrator is carrie at the switch handle end of the coil and is cut into th coil circuit by pressing the button that is seen i the center of the switch plate. Normally this vibrato is out of circuit, but pressing the button closes th contacts and a stream of sparks is produced. Th vibrator is kept in action by turning the button to

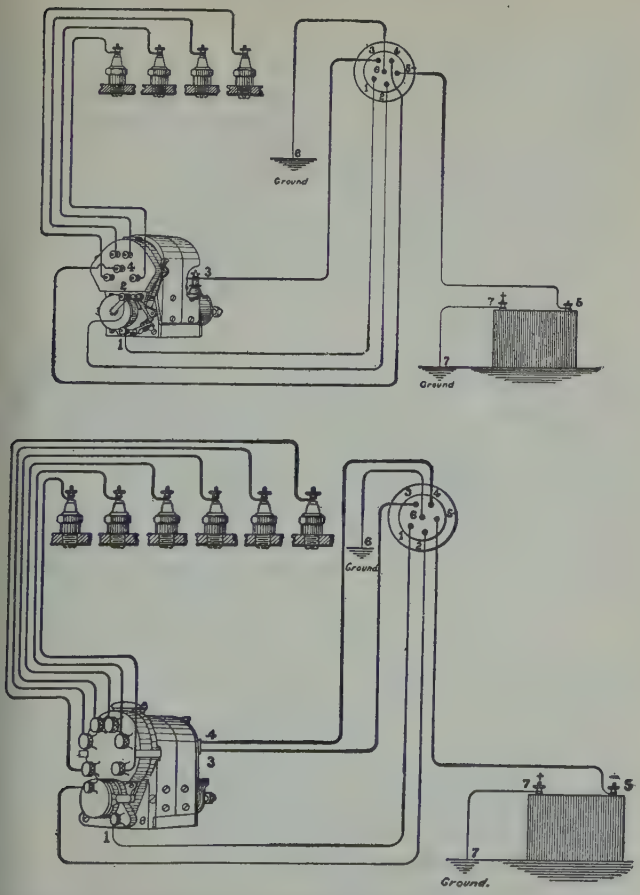


Figure 147.—Wiring of Dual High Tension Magneto. Top: Open Frame Machine. Bottom: Enclosed Instrument (Bosch).

ward the right so that the arrow points to the word "START."

External wiring for the Bosch dual systems is shown in Figure 147 and the internal connections of the coil in both positions are shown in Figure 148. The connections from the coil terminals are:

1—To battery breaker on magneto.
2—To magneto armature grounding terminal.
3—To magneto secondary terminal.
4—To center of magneto distributor.
5—To negative terminal of battery.
6—To ground.

In the battery position: The coil vibrator and primary winding are connected to the battery breaker through terminal 1. The magneto primary is grounded through terminals 2 and 6, which are connected by the switch movement. The magneto secondary is open circuited at terminal 3, from which there is now no internal connection in the coil. The coil secondary is connected to the center of the distributor through terminal 4. The remaining end of the coil primary is connected to the battery through terminal 5. Thus the battery circuit is complete through the coil primary, the coil vibrator, and the battery breaker on the magneto.

In the magneto position: The battery breaker is grounded with terminals 1 and 6 connected by the switch movement. The armature ground is removed by open circuiting terminal 2 in the coil. The magneto secondary is connected to the distributor by the connection now made between terminals 3 and 4 in the coil housing. The battery is disconnected by open circuiting terminal 5 in the coil. Thus the battery is cut off and the magneto secondary is connected

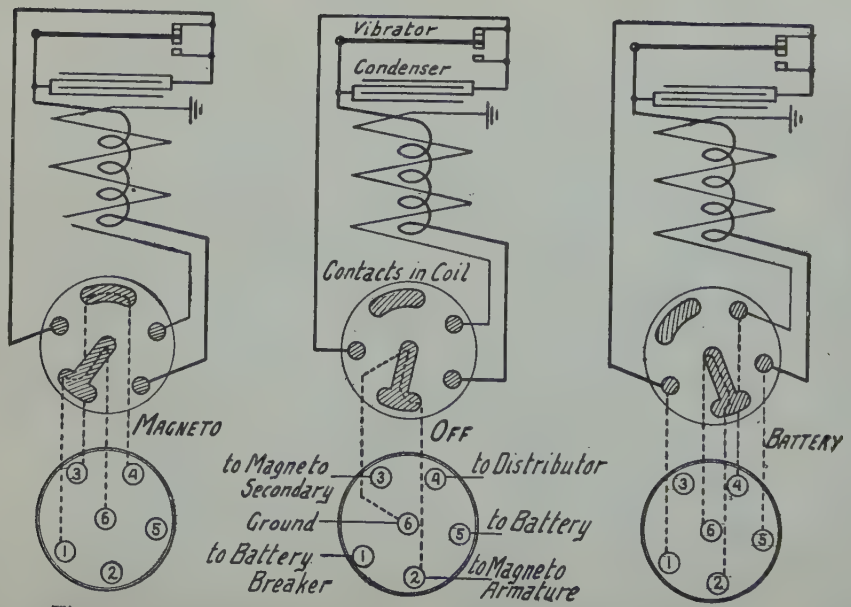


Figure 148.—Bosch Dual Coil in Magneto, Off, and Battery Positions.

to the distributor with the magneto primary operating because now ungrounded.

NU TYPE BOSCH MAGNETOS

The NU magneto differs from practically all other instruments of Bosch or other makes in doing away with the usual type of distributor and replacing it with two collector or slip rings in a manner that will be explained. This magneto is suitable only for comparatively small engines having four cylinders and of the four cycle type.

The principle of operation and the electrical circuits of the NU magneto are shown at the top in Figure 149, which is a schematic diagram. The construction of the driving end of the armature on which are carried the two collector rings with their four brushes is shown at the bottom of Figure 149.

In the NU magneto, unlike most other machines, the secondary winding is completely insulated from the primary and from any ground connection within the magneto. The two ends of the secondary winding are connected to two metal segments, one segment in each of the collector rings.

It will be seen that two of the four brushes receive current simultaneously and each is connected by its wire with the spark plug in one of the cylinders. The secondary circuit therefore always contains two spark plugs and a spark will pass in two cylinders at the same instant.

With the piston of number one cylinder at top center following the compression stroke a spark will pass at its plug. At the same instant a spark will pass at the plug in number four cylinder, whose piston is also at top dead center, but following the

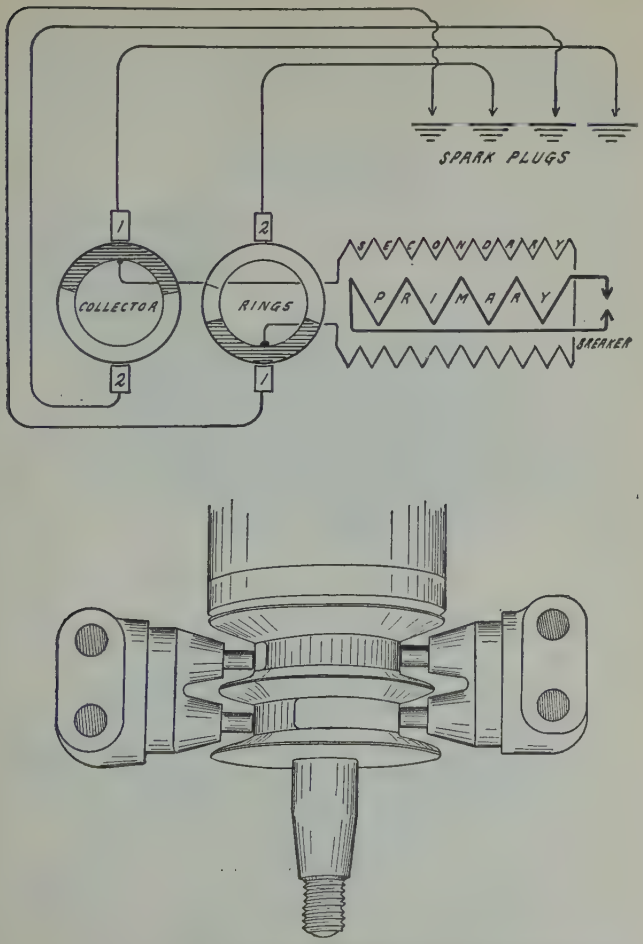


Figure 149.—Circuits and Distributor Construction of Bosch NU Magneto.

exhaust stroke and with the combustion space filled with dead gas. Consequently there is no ignition in cylinder four, although ignition does take place in number one, which is filled with fresh compressed mixture. A similar condition exists between cylinders two and three so that but one ignition takes place, although two sparks pass.

Some care should be exercised in the setting and timing of the NU instruments to avoid having the spark take place too late. It will be realized that with an extremely late timing, the spark taking place in the dead cylinder might come after the piston had started down on the inlet stroke which follows the exhaust. Should the inlet valve in that cylinder have opened before the spark passes, the fresh incoming mixture might become ignited, thus causing a back fire. While this is a remote possibility, it should be considered in the timing operation.

B TYPE BOSCH MAGNETOS

The construction of the B type magneto is shown in Figure 150 and the electrical circuits in Figure 151. The most noticeable difference between this and other magnetos is in the vertical distributor, which is similar to those used with battery ignition systems. The breaker, however, is of typical Bosch magneto construction and is mounted on the end of the armature shaft as usual.

Bearing on the collector ring at one end of the armature is the collector brush, and a high tension cable carries the spark current from this brush to the center terminal of the distributor. The distributor is of the wipe contact type, using carbon brushes.

A safety spark gap is formed by placing a screw in the top of the magneto frame at the distributor end so that the end of this screw projects into the

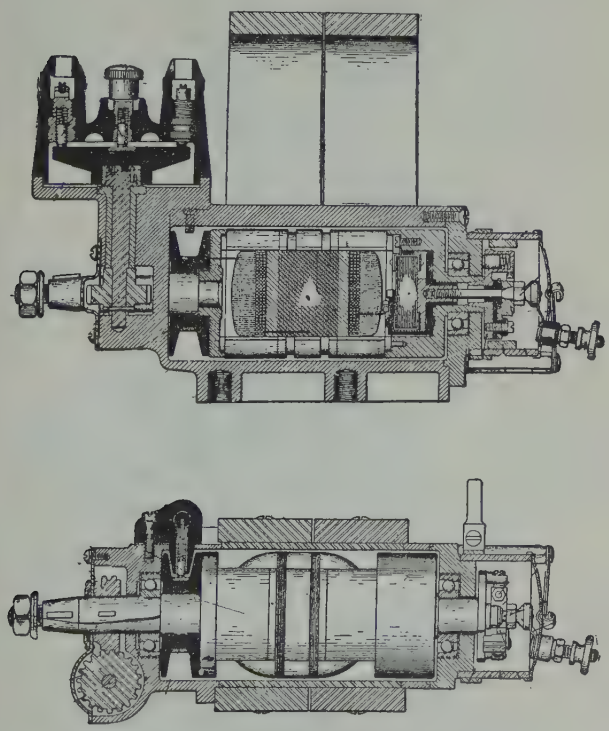


Figure 150.—Construction of Bosch B-Type Magneto.

space over the center of the collector ring. High tension current may jump across the gap from ring to screw, should there be an open circuit in the regu-

lar secondary circuit. In other respects this magneto is similar to the DU types.

The B-4 four-cylinder magneto is driven at crankshaft speed for four cycle engines, and the six-cylinder B-6 magneto is driven at one and one-half times crankshaft speed for four cycle engines. The direction of rotation is marked by an arrow on the gear cover plate at the drive shaft end of the magneto. Timing is done as with any other magneto by making the

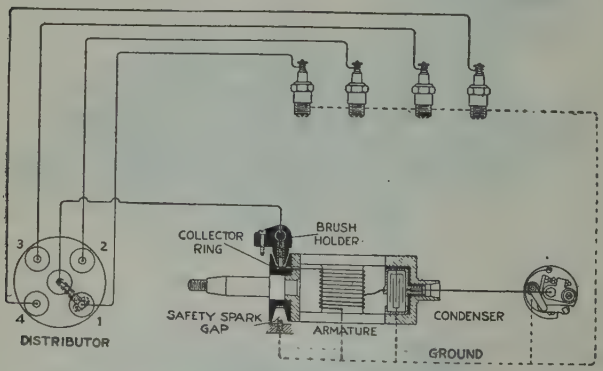


Figure 151.—Circuits of Bosch B-Type Magneto.

drive connection so the breaker opens at top center with the control retarded.

EISEMANN G4 MAGNETOS

In common with all Eisemann magnetos made during recent years, the G4 types are of the true high tension variety having both high and low tension windings on the armature and generating the secondary current ready for the spark plugs without

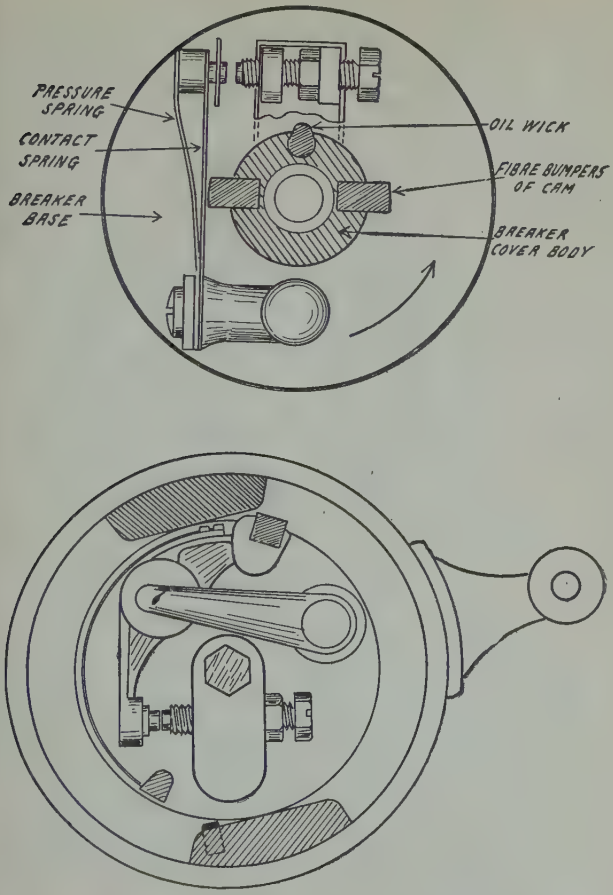


Figure 152.—Breakers of High Tension Magneto. Top: Cams Carried at Center of Assembly. Bottom: Cams Carried in Rim of Housing. (Eisemann, "G4" Models.)

additional outside parts. The first G4 instruments are designated as Edition One and a later model is Edition Two, these being generally written, I Edit and II Edit respectively. The difference between the two magnetos is found in the breaker, the pole pieces and in the frame and housing construction.

Breaker Edition One.—This breaker design is shown at the top of Figure 152. The cam is stationary except for the slight movement required in advance and retard, while the breaker arm and contact carrying parts are mounted on the end of the armature shaft and revolve around the cam. On the revolving breaker base are carried two members with the two contact points. The fixed contact is mounted on the end of an adjusting screw and supported on a block which is insulated from the base proper by a fibre washer. Current from the armature low tension winding comes to this insulated block and fixed contact through a long screw which fastens the breaker to the armature shaft. The movable contact point is carried at the end of a flat spring called the contact spring and the other end of this spring is screwed to a hollow post inside of which is a carbon brush which maintains a sliding contact with the frame of the magneto and serves to ground the breaker base and the movable contact. Back of the contact spring, and separated from it at the contact end by a fibre block, is the pressure spring which serves to close the contacts when not acted upon by the cam. All of the parts described in this paragraph revolve with the armature.

Over the breaker end of the magneto fits the cover of which the advance and retard levers are a part. Except for a movement of thirty degrees for advance

and retard, this cover is stationary and at its center are carried the parts of the cam shown in Figure 152 as attached to the breaker cover body. These parts include two fibre bumpers directly opposite one another and an oil wick at the top. As the breaker base revolves, the contact spring comes in contact with these fibre bumpers and as the spring rides over the bumper the contacts are separated in the position shown in the illustration.

Breaker, Edition Two.—The breaker mechanism of this model is similar to the breaker used with older models, EU, ED, EM and others.

The design is shown below in Figure 152. The revolving parts which carry the contact points are carried by the breaker plate which is attached to the end of the armature shaft by a long screw with a tapering head and held in place by means of a key and keyway. On this revolving base, but insulated from it by a fibre washer, is a block through which passes the adjusting screw carrying one of the contact points. The other contact point is carried on one end of a rocker arm which is supported by a pivot bearing with a fibre bushing. The pivot is covered by one end of a flat spring and the tension of this spring serves to hold the rocker arm on the bearing. The other end of this rocker arm carries a fibre bumper which rides over the cams and forces the contacts apart by moving the arm on the pivot.

Inside of the breaker housing are carried two steel cams set diametrically opposite each other and over which the fibre bumper of the rocker arm passes during the revolution of the armature and breaker base. During this passage the arm moves, separating the contacts, and the spark takes place.

Armature.—The armature is of the conventional H slot type and is shown in Figure 153. In the slot is carried the double armature winding and at the drive end of the slot is placed the condenser. The armature end plate at the drive end carries a brass slip ring against which bears the carbon grounding brush, this brush being supported by a screw set into the base of the magneto. Through this brush are grounded the primary winding, the secondary winding and the condenser.

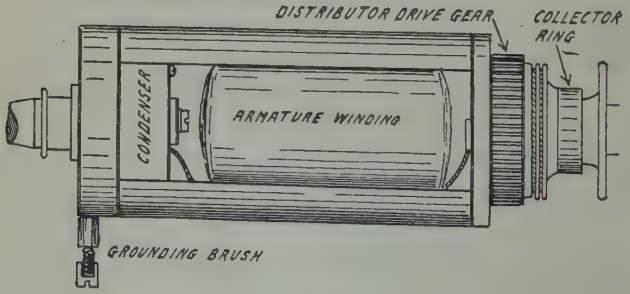


Figure 153.—Armature of High Tension Magneto (Eisemann)

At the breaker end of the armature is the pinion which drives the distributor gear and separated from this pinion by a series of insulating corrugations is the high tension collector ring to which one end of the high tension winding of the armature attaches. Bearing against this ring is the collector brush which carries the high tension current to the center of the distributor cap.

Distributor.—The Eisemann distributor as shown in Figure 131 is of the wipe contact type having a metal segment set into the rotor which is carried by

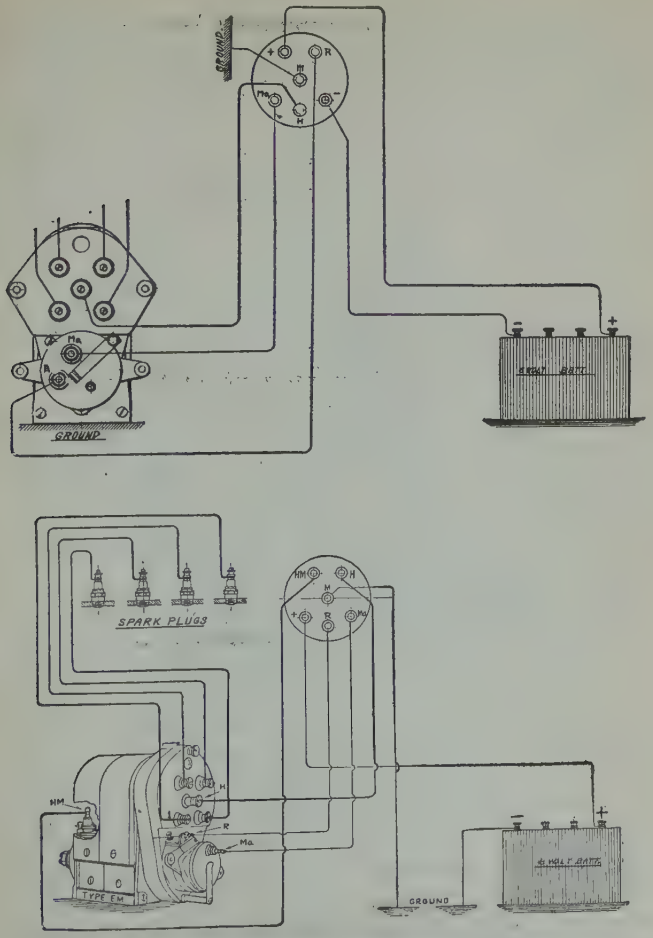


Figure 154.—Wiring of Dual Magnetos. Eisemann Model "EB" at Top and Model "EM" at Bottom.

the distributor gear. This segment revolves past a series of carbon brushes, one for each cylinder of the engine, which are mounted in the distributor cap. In the center of the distributor cap is another brush which bears against the inner end of the revolving segment and this brush is connected through the body of the distributor cap with the collector brush which takes the high tension current from the collector ring on the end of the armature.

A safety spark gap is provided by means of one or two small brass screws which pass through the armature housing and have their inner ends extending to within about 3/8 of an inch of the collector ring carried by one end of the armature shaft.

Dual System.—This type of Eisemann magneto is also built as a dual instrument by modifying the breaker and distributor to allow separation of the battery current from that generated by the magneto armature. Wiring for Eisemann dual magnetos is shown in Figure 154.

The breaker housing has two compartments, one being of the type already described for single magneto ignition and the other carried outside of the first one and containing another complete breaker mechanism through which the battery current passes. This breaker arm is so placed in relation to the actuating cams that the opening of the contacts occurs 10 degrees later in the revolution of the armature than does the opening of the magneto contacts. The advance and retard is the same as for the magneto side, being operated from the same timing arm. This dual breaker is somewhat similar to the one already described as on Bosch magnetos.

The distributor for the dual instrument is similar

to those used with the single ignition types except that there is no direct connection through the cover from the lower carbon brush which touches the collector ring and the center brush which touches the distributor rotor. Instead, the collector ring brush is

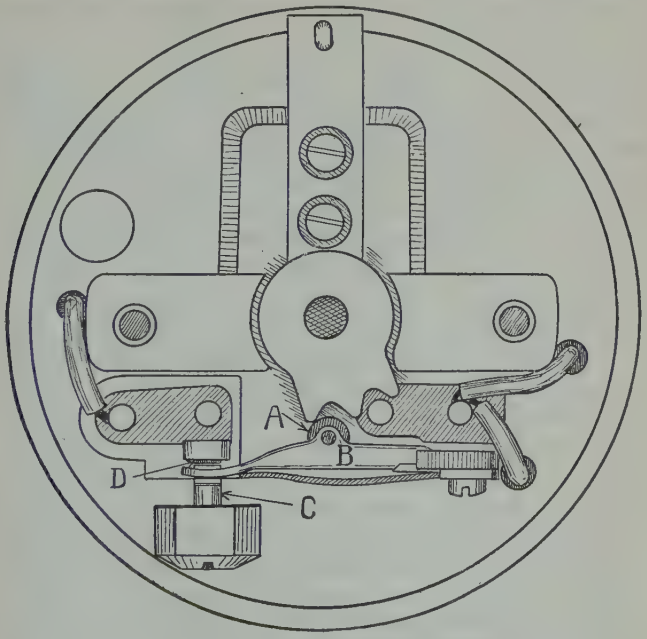


Figure 155.—Manually Operated Breaker in Coil (Eisemann).

connected with one of the terminals and from this terminal the high tension magneto current may be led through the switch and back to the center brush with magneto ignition in use, or, the high tension battery current may be led from the coil to the

center brush of the distributor with the battery ignition in use. With a four cylinder magneto there are then six terminals on the distributor; four being for the spark plug wires, one for the collector ring brush and one for the center distributor brush. In all other respects the dual instrument is the same as the single ignition type.

The coil unit used with dual magnetos contains, in addition to the coil itself, a device for starting the engine by manual production of a spark and the ignition switch. The sparking mechanism is illustrated in Figure 155 and consists of a ratchet having three teeth which engage with a roller A on a lever B. This lever is mounted at one end on a hinge, while at its other end is a platinum contact extending through it to provide a contact on both sides of the lever. The lever is operated by twisting back and forth a starting handle which appears on the ignition switch cover. The lever B then makes and breaks the primary current from the battery by making contact alternately with the fixed contacts C and D. This results in a shower of sparks occurring at the spark plug in the cylinder which is ready for firing and if there is a combustible mixture in the cylinder the engine will start.

Another type of coil is made which does not include the mechanical breaker just described, but which, in place, is fitted with a push button which gives but one spark in place of the series of sparks. This type is generally used on cars fitted with engine starters, and is similar to the device in Bosch coils which is illustrated in the center of Figure 100.

With the dual system, battery current is carried through the dash coil and the battery breaker in the

battery position. In the magneto position the high tension current from the magneto is carried to the distributor through the switch in place of going directly from the magneto armature to the center of the distributor or the rotor.

EISEMANN AUTOMATIC ADVANCE

The Eisemann magneto with its automatic advance is shown in Figure 156. This is a modification of the fly-ball type of governor adapted to change the relation between the shaft driven from the engine and the shaft passing through the armature and to the breaker of the magneto. To this armature and its shaft is attached a box-like guide within which is carried a block designed to slide back and forth in the guide. Through this block is a hole and two slots or keyways which are so cut that they fit over and engage two keys on the outside of the driving shaft. These driving shaft keys and the keyways in the sliding block follow a curved or screw-like path around the shaft and through the block so that if the block be slid along the shaft the curving of the keys will cause the block to turn for a part of a revolution about the shaft as it slides. Inasmuch as the block is carried inside of the guide which is fastened to the armature shaft the armature and breaker shaft will likewise revolve for this same part of a revolution with reference to the driving shaft. The armature shaft then drives the armature and breaker through the two keys, the square block and the guide. To the block are pivoted two arms of the weights shown in the illustration and the other arms of these weights are fixed to the guide on the armature. As the driving shaft rotates in proportion to

the speed of the engine, the weights tend to fly outward and, according to the throw of the weights, the armature and breaker are shifted with respect to

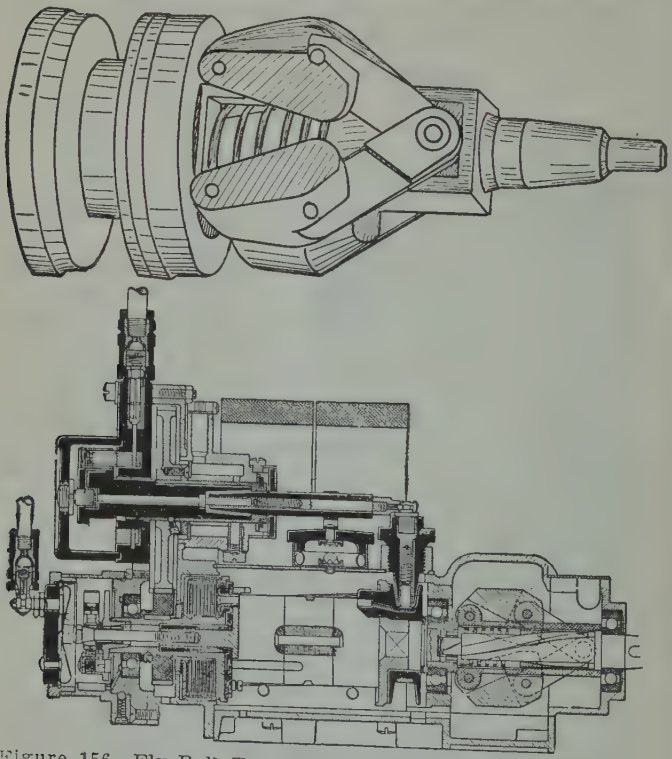


Figure 156.—Fly-Ball Type of Automatic Advance Governor. Top: Governor. Bottom: Magneto Installation (Eisemann).

the driving shaft, thus advancing the time of ignition. As the block is drawn endwise by the weights a coiled spring carried around the shaft is com-

pressed and the tension of this spring, opposed to the force of the weights, determines the amount of advance.

This type of automatic advance mechanism may be suited to various engines and provide maximum advance of from twenty to sixty degrees by using shafts having keys of various pitches and by using springs with varying strength. In common with practically all other automatic advance devices, there is no provision for adjustment once the engine has been properly fitted except by changing the spring tension.

K-W INDUCTOR MAGNETOS

These magnetos are of the revolving inductor type with both high and low tension windings around the center of the inductor as shown in Figure 157 illustrating the Model T magneto. These instruments are therefore of the true high tension type, requiring no outside coil. For four-cylinder engines, the drive is at crankshaft speed, and for six-cylinder engines at one and one-half times crankshaft speed. The direction of rotation is shown by the arrow on the end cap.

The rotation may be changed by removing the breaker cam and replacing it the other side out, then removing the screws holding the distributor block and replacing them in the other set of holes. The construction of the breaker is shown at the bottom of Figure 157. The arm is operated by the small cam on the end of the inductor shaft.

The two inductors are placed crosswise of the shaft and at an angle of ninety degrees with each other. The circuit of the primary winding is completed through the breaker contacts and between the con-

tacts is connected the condenser carried above the rotors under the arch of the magnets at the drive end of the machine. One end of the high tension winding is grounded and the other end leads through the vertical connection to the high tension lead run-

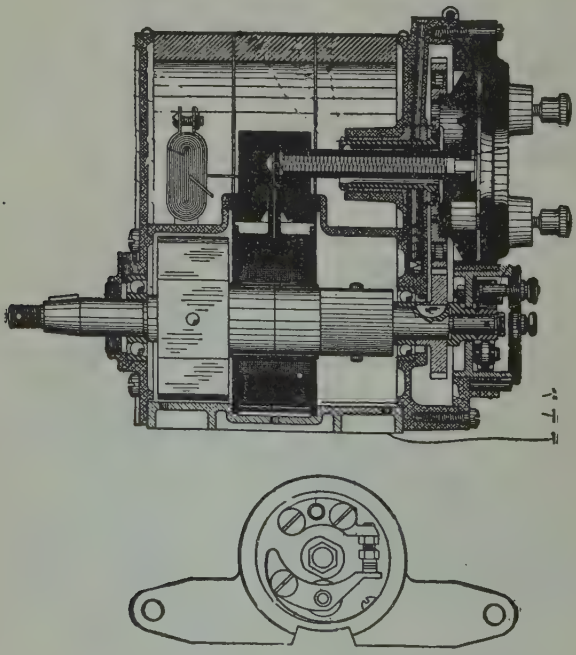


Figure 157.—The K-W Model T Magneto.

ning to the center of the distributor. The distributor is of the wipe contact type with a segment let into the rotating member and traveling under the ends of small carbon brushes in the distributor cap.

The stationary contact of the breaker is carried on an insulated block and connected with the primary winding. The breaker arm, carrying the other contact, is grounded and connected through ground to the other end of the primary winding. A grounding terminal for the switch is carried on the breaker cover. The stationary contact has a screw adjustment for altering the gap.

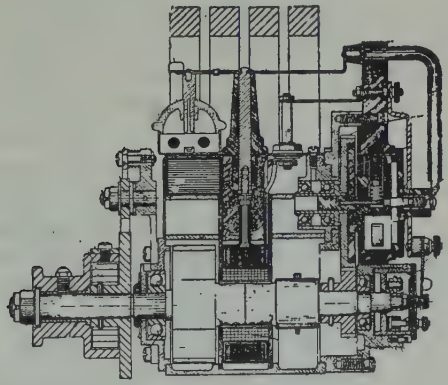


Figure 158.—The K-W Model H Magneto.

The construction of the type H magneto with high magnets is shown in Figure 158. The rotor design and the placing of the primary and secondary windings are the same as in the type T. The secondary connection is made through a conductor bar to a safety gap at the drive end of the machine and to a high tension lead coming down to the center of the distributor at the other end. The condenser is carried at the drive end just under the safety gap housing. The construction of the breaker is the same

as the T type shown in Figure 157. All of these magnetos are timed to the engine and the distributor is wired to the spark plugs as with any other high tension machine.

REMY INDUCTOR MAGNETOS

Early types of Remy magnetos were of the inductor type, known as models RD and RL, both being of similar construction as shown in Figure 159. The inductors in this machine are constructed of iron laminations and each one is balanced by attaching on the opposite side of the drive shaft a weight of non-magnetic metal. The construction of the breaker and distributor may be clearly seen from the illustration. The breaker contact gap is provided with an adjustment which may be altered from outside the housing. The cam is kept covered with a thin film of lubricant by means of a small wick oiler which is shown. The distributor is of the jump spark type with the segments for the spark plug terminals imbedded in the housing wall. In this instrument the central carbon brush of the distributor is mounted in the rotating member while the distributor cover carries a small metal boss connected with the terminal which carries the wire from the high tension winding of the transformer coil.

The electrical circuits for the RL magneto are shown in Figure 160. The coil switch is fitted with a button which opens and closes the battery circuit through the coil primary, thus producing a spark in the plug of the cylinder ready to fire. It should be noted that neither side of the battery is grounded. It is not advisable to use storage batteries with Remy inductor magnetos for a supply of battery ignition

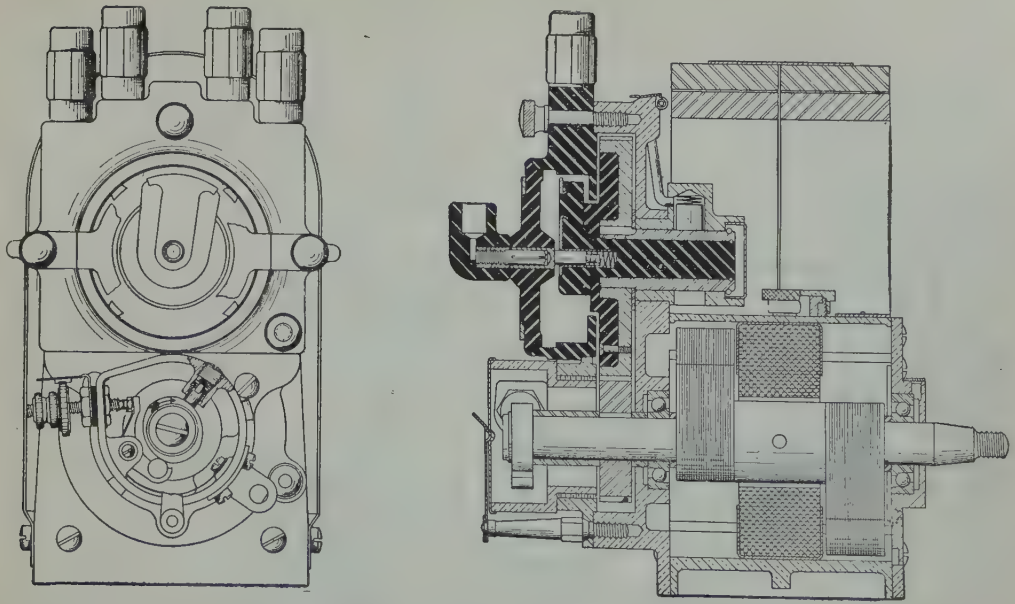


Figure 159.—Construction of Inductor Magneto (Remy, Model "RD").

current for starting, dry cells being recommended in all cases.

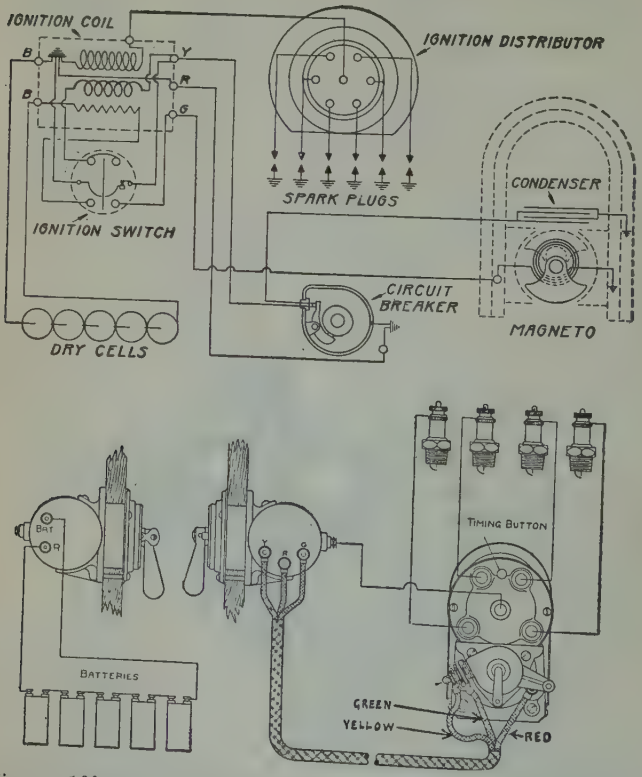


Figure 160.—Circuits of Remy Type RL Inductor Magneto.

REMY TRANSFORMER COIL MAGNETOS

While the earlier models of Remy instruments were of the inductor type, all of the later machines

have been built on the transformer coil principle. The inductor models are described in the chapter following. All of the circuits, both internal and external, of the transformer coil types are shown in Figure 114. The coil carries six terminals, two of which are attached to the battery, one to the magneto distributor and the remaining three to the magneto armature, breaker and ground connection. The green wire from the magneto carries the low tension armature current to the switch and the primary winding of the coil. The yellow wire provides a connection from the primary winding of the coil to the breaker carried on the magneto. The red wire serves to ground the primary and secondary winding of the coil. This wiring is typical of all similar Remy magnetos, and is shown in Figure 161 for both single and two spark instruments.

Construction.—These machines are made for either single or two point ignition, the two point types differing from their single point counterparts only in having two distributors, one on each end of the magneto, from which wires are run to the two sets of spark plugs required by this form of ignition. The magnetos are designed to be water and dust proof by having the end plates machined to fit the magnets and the distributor cover machined to fit the gear case. Packing is then used in the joints.

The armature is of the "H slot" or shuttle type carrying a single low tension winding. At the drive end of the armature is a collector ring on which rides a carbon brush through which, together with the green wire, the armature current is delivered to the primary winding of the coil.

The breaker consists of a cam mounted on and

revolving with the armature drive shaft, and operated by the cam, a breaker arm hinged at one end, having a fibre bumper for the cam near its center and carrying the contact points at the free end. The

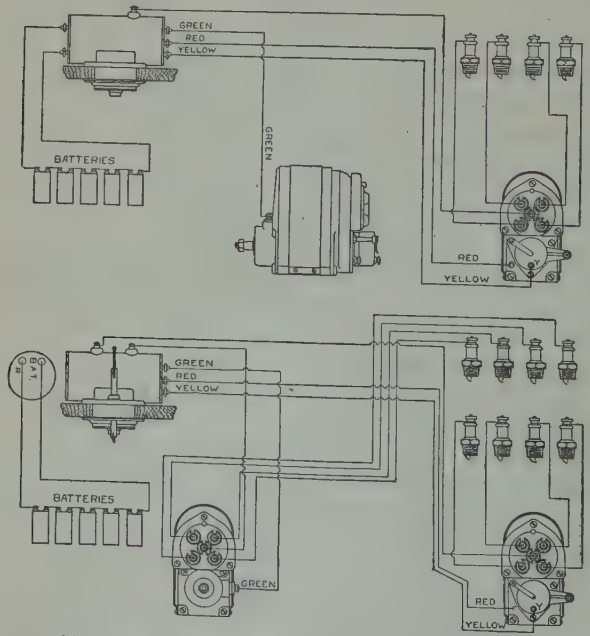


Figure 161.—Wiring of Remy Transformer Coil Magnetos. Top: Models "P" and "32." Bottom: Two Spark Models "30" and "31."

advance and retard lever may be located on either side of the machine as the breaker and housing are reversible. The timing range is about 35 degrees.

The condenser is flat and imbedded in insulating compound. The condenser housing with its cover

forms a cover for the armature and is carried underneath the arch of the magnets and resting on the pole pieces.

The distributor is of the wipe contact type having a carbon brush carried on the large distributor gear and making contact with the center segment in the distributor cover and with the segments in the cover from whose terminals wires lead to the spark plugs.

The coil and switch are combined in one unit with only the switch appearing in the driver's compartment. The coil used with two point ignition magnetos differs from the single point type in having two high tension terminals, one from each end of the secondary winding. One terminal is connected with the distributor at one end of the magneto while the other terminal serves the second distributor. The two point coil is also fitted with an additional switch by means of which one set of plugs may be cut out and the complete high tension circuit completed through the remaining set and the coil winding which is then grounded at one end.

Timing.—For convenience in setting the magneto the distributor gear is provided with a depression near its circumference and mounted in the distributor cover near the top is a button whose inner end, when pressed by the operator, will drop into the depression in the gear. With the button holding the gear by means of the depression, the breaker contacts are just about to separate and cause a spark and the distributor is in position to deliver the high tension current to the plug in number one cylinder. Timing is accomplished by bringing the piston of number one cylinder to top center following the compression stroke and leaving it there. The timing button is

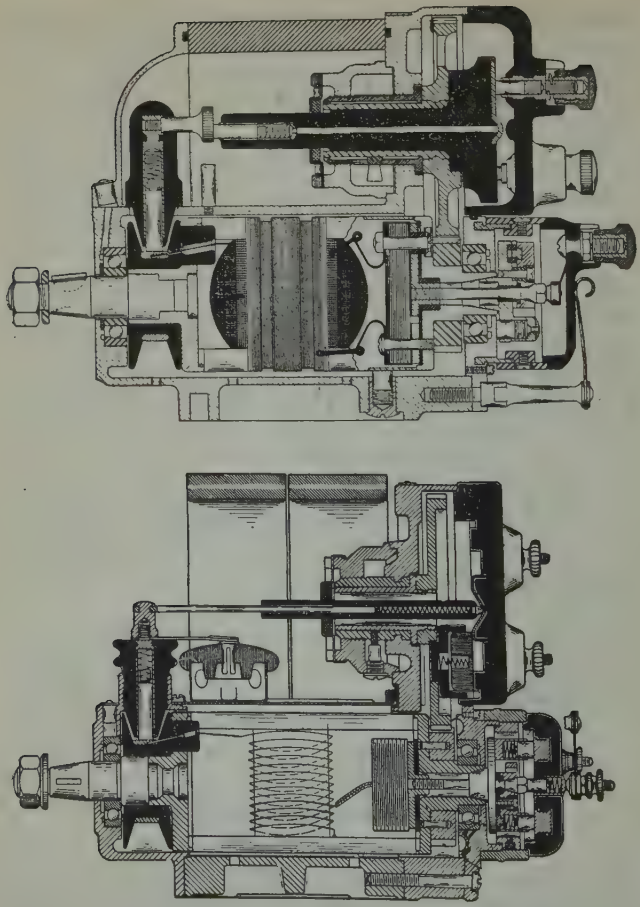


Figure 162.—Simms Magnetos. Top—Model C Waterproof Type. Bottom—Model SU.

then pressed and the armature shaft turned until the button is felt to drop into the gear depression. The coupling between armature shaft and engine drive shaft is then secured. If the magneto shaft revolves clockwise, viewed from the drive end, the distributor terminal for number one cylinder is at the lower left hand corner of the distributor, while if driven anti-clockwise the terminal for number one is at the lower right hand corner with the setting made as described.

SIMMS MAGNETOS

All Simms magnetos are of the true high tension type, having both the primary and secondary windings carried on the revolving armature. The construction of the Model C waterproof instrument is shown in Figure 162. One end of the primary winding is grounded through the grounding brush under the breaker end of the armature and the other end of the primary is connected with the insulated stationary breaker contact. The other breaker contact is grounded on the breaker plate, which in turn grounds through the small carbon brush carried in the back of the plate and rotating on the end frame of the magneto. The condenser is carried in the end of the armature and connected between the insulated breaker contact and ground. The distributor is of the wipe contact type.

The construction of the type SU magneto is shown in Figure 162. Figure 163 shows the internal connections and Figure 164 the external connections of this machine when used for dual ignition. With the dual ignition system there are two small carbon brushes carried by the breaker and rotating around commutator segments in the breaker cap. With the

switch in the magneto position the battery is disconnected and the magneto operates as any high tension machine. In the battery position of the switch, the battery is connected in series with a battery coil and with the primary winding of the magneto so that the battery current flows through the magneto armature winding to secure the necessary induced current in the magneto secondary winding. Rotation

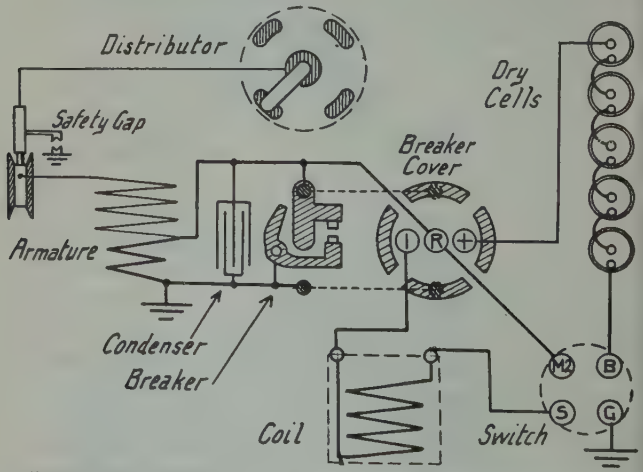


Figure 163.—Circuits of Simms Dual Ignition System.

of the two breaker brushes over the commutator changes the direction of battery current through the magneto primary so that the polarity of the two currents is kept the same during the whole revolution.

On some cars the terminal R on the breaker cover, shown connected to terminal M2 of the switch, is connected to some other form of magneto grounding switch. Then the terminal of the coil that is shown

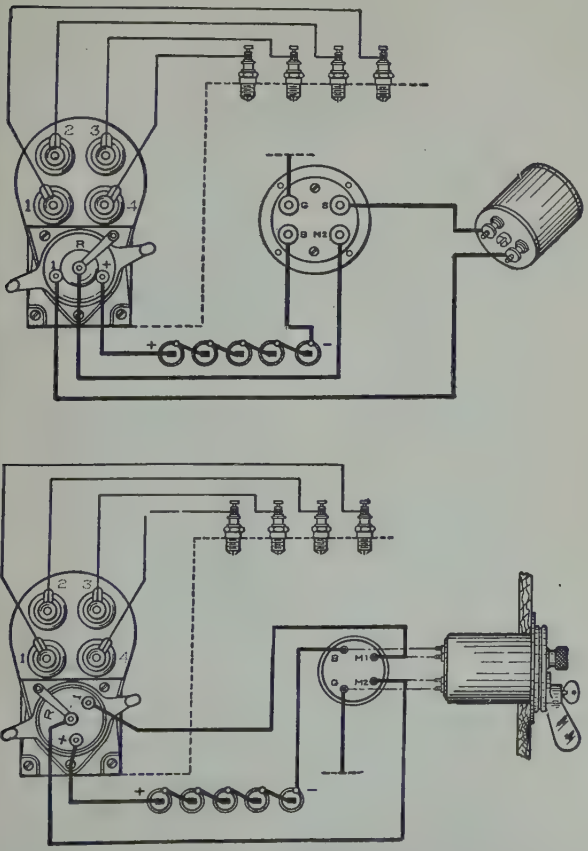


Figure 164.—Wiring of Simms Dual Magnetos. Top—Model SU-D. Bottom—Model SU-S.

connected to switch terminal S is connected to the negative of the dry cells through a second separate switch. On Maxwell cars this second dry cell switch is operated with the starting switch, giving battery action while cranking takes place. It will be seen that this dual system is similar to the Bosch duplex system described in the preceding chapter.

SPLITDORF INDUCTOR MAGNETOS

Splitdorf models 46, 448 and 648, also Dixie models, are described first in the following pages, all of these types being similar in construction. The operating principles of all Splitdorf inductor magnetos may be understood from Figure 165.

The rotating member, or rotor, consists of two revolving wings N and S, shown at 1 in the illustration, which are separated by a bronze center piece. These wings are carried by the magneto drive shaft and revolve between the poles of the magnets, one rotor revolving adjacent to the North pole while the other revolves close to the South pole. Because each rotor always revolves close to its own pole of the magnets, they always maintain the same magnetic polarity, one always being positive while the other is always negative.

Again viewing a section of the magneto and looking across the magnets as in 2, 3 and 4 of Figure 165, in place of through the arch as in 1, it will be seen that the rotor is enclosed by the lower ends of an arched field structure, on the upper part of which are placed the coil windings. As the rotor revolves it causes the magnetic lines of force to be changed about so that the magnetism flows back and forth through the field structure and the core of the

windings, first in one direction, then in the other, according to the position of the rotor in relation to the poles of the field structure.

Still referring to Figure 165 it will be seen that, by rotating the wings very close to the ends of the magnets, they are in effect the rotating poles of the

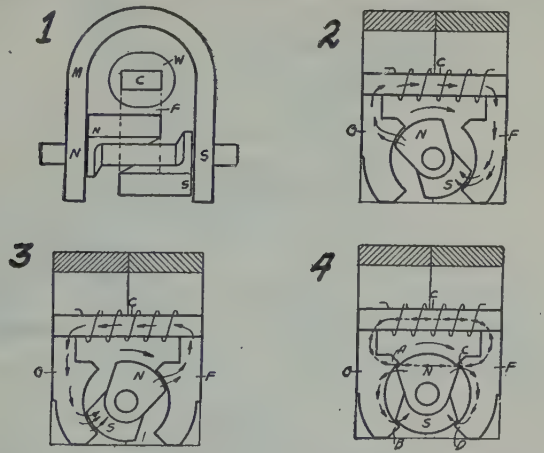


Figure 165.—Principle of Inductor Magneto with Rotating Magnet Poles.

magnet. At right angles to the rotating pole pieces or wings is the field structure consisting of laminated pole pieces F and G carrying across their top the windings W. When N is opposite G the lines of force flow from one pole N of the magnet to G and through the core C to F as shown in 2 of the illustration. As shown at 3, the pole N has moved over to F and the direction in which the lines of force flow is reversed through the core and windings, now passing from F through C to G. At 4 in the illus-

tration the rotating pieces occupy a position midway between the two foregoing so that the field pieces F and G are magnetically short circuited and all the lines of force are removed from the core C.

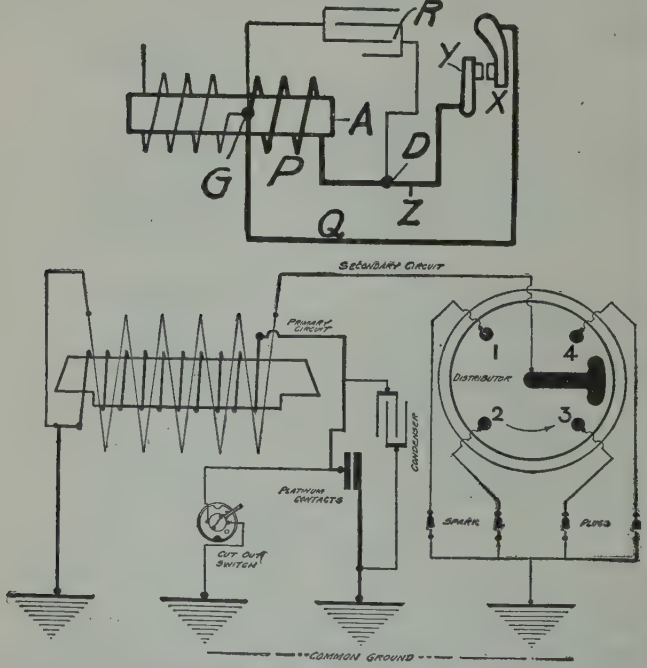


Figure 166.—Internal Circuits of Inductor Magneto. Top: Primary Circuit. Bottom: Primary and Secondary Circuits.

Primary and Secondary Circuits.—The primary circuits are shown at the top of Figure 166. The core of the coil A is stationary, being represented in the preceding figure by C. The inner end of the

primary winding P is grounded on the core. Q indicates the metal frame of the machine. The condenser R is carried just above the coil and is removable by taking out two screws. The terminal D is a screw on the head of the coil and the wire Z connects directly to the contact Y of the breaker.

The secondary circuit is also shown at the bottom of

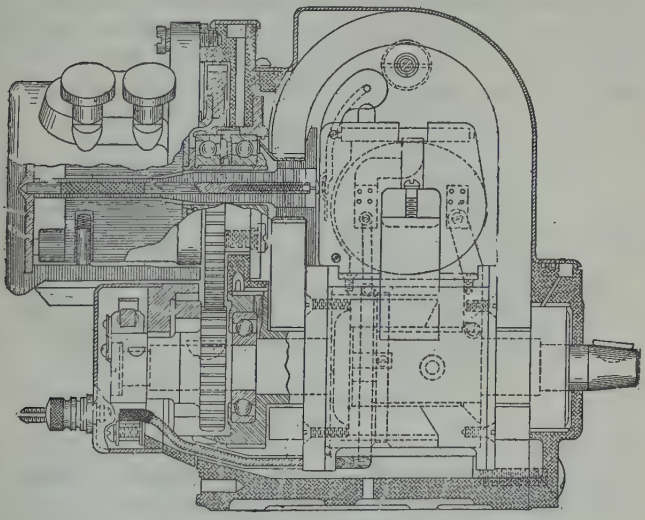


Figure 167.—Construction of Magneto for Eight Cylinder Engines.

Figure 166. One end of the secondary is grounded while the other is connected to the rotor of the distributor which sends the high tension current through the spark plugs back to the ground. A safety spark gap is provided between the framework of the machine and the central connection for the distributor.

Breaker.—The breaker is shown in Figure 168.

The parts of the mechanism shown in the illustration are stationary while the magneto is running. The adjustment between the contact points X and Y is made by the screw which is shown. These contact points should separate when the air gap between one of the rotor wings and the pole piece carrying the coil is between 15 and 35 thousandths of an inch. The breaker is made adjustable as shown at the right in Figure 168 so that this relation may be secured without difficulty and may be regained should the fibre bumper become worn. The bearing holder in which the breaker base is fastened has slotted holes, permit-

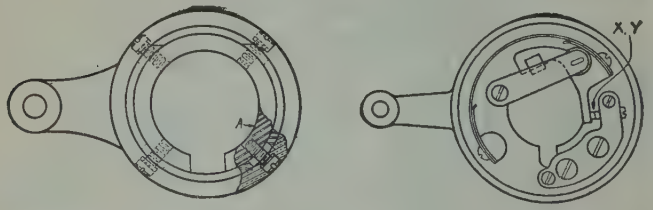


Figure 168.—Construction and Adjustment of Dixie Magneto Breaker.

ting the breaker base to be rotated several degrees in either direction from its original position. As the breaker parts are mounted on the base, the positions of the rotor at which the cam causes the contacts to separate can be varied by as many degrees as the breaker can be moved. The four screws which pass through the breaker base and bearing holder thread into the clamping ring A. To adjust the breaker it is necessary to loosen the four screws, then; if the air gap between rotor wing and pole piece is too small, rotate the breaker base in the same direction that the cam rotates while in operation. If the gap

is too large, rotate the breaker base in the direction opposite to that of the cam's rotation. The screws should then be securely tightened.

Advance and Retard.—It will be noted from the foregoing explanation of the breaker base construction that this member is securely fastened to the body of the magneto. This fastening takes place between the breaker base and the pole piece structure on which is carried the coil winding and between the

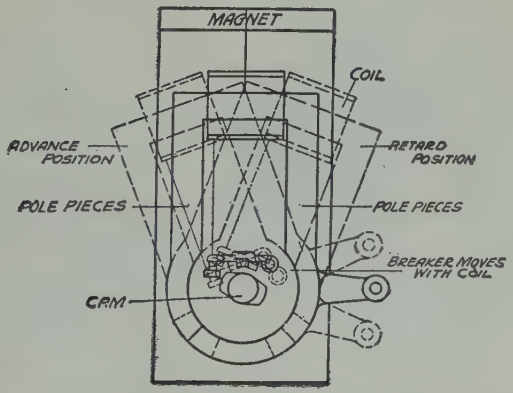


Figure 169.—Advance and Retard of Rocking Magnet Magneto (Dixie).

ends of which the rotor turns, therefore the relation between the point at which the breaker contacts separate is always the same with reference to the relative positions of the rotor and its pole pieces, this opening taking place at the instant of greatest current volume in the coil and just as the magnetic flux undergoes the greatest change.

The advance in these first types is obtained by

rocking the entire pole piece structure together with the coil windings and the breaker base between the arch of the magnets as shown in Figure 169. This rotation of the breaker base with the contacts changes the relation of these parts to the cam on the drive shaft as shown in the illustration so that the time of opening and closing the contacts may be made

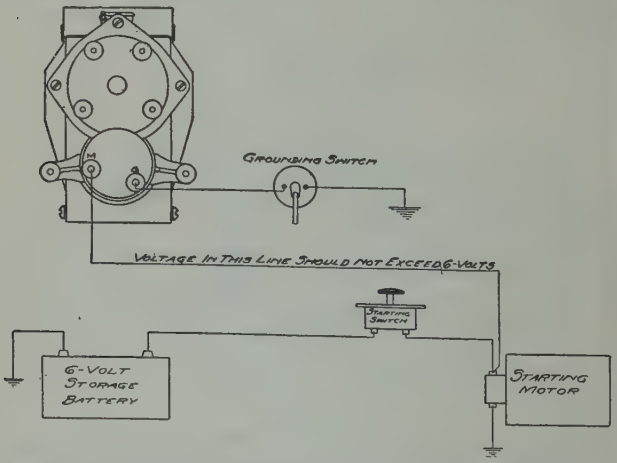


Figure 170.—Starting Connection on Splitdorf Magneto.

earlier or later while still maintaining the same relative positions of the rotor and pole pieces.

Starting Connection.—Models 449 and 649 have two terminals on the breaker cover as shown in Figure 170. Terminal M on the breaker is connected with the insulated terminal of the starting motor, the terminal carrying the large cable from the starting switch. Terminal G is the regular grounding terminal connected with the magneto switch.

In these magnetos the primary winding is not grounded, but is connected to terminal M and grounds through the starting motor while the magneto is operating. While starting, with the starting switch closed, the battery current flows to the starting motor and also to the magneto terminal M and through the primary winding of the magneto to ground through the breaker contacts. Interruption of this current by the breaker contacts produces a high tension current no matter how slowly the engine is being cranked.

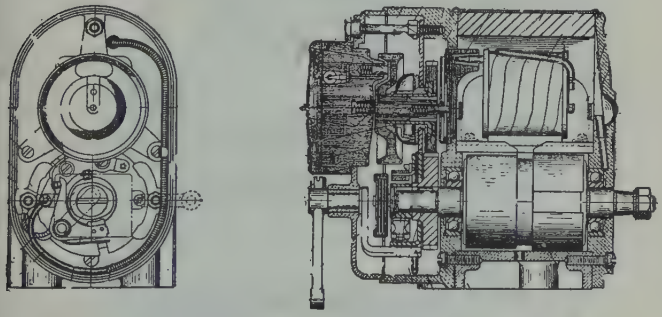


Figure 171.—Splitdorf Type S Magneto.

SPLITDORF S AND SS MAGNETOS

These machines are also of the inductor type and use the same magnetic circuit of rotating wings and arched construction to carry the coil windings as in the type already described. In other important particulars, however, the construction differs. The details of the type S are shown in Figure 171.

The breaker mechanism is attached to a steel base carried in the frame and arranged to be moved by

the control arm for advance and retard. The breaker cam is carried on the end of the rotor shaft. The breaker arm is insulated from its stud and is then grounded through a stranded copper strip. A flat spring fastened to the metal case of the condenser keeps the breaker arm on its stud. The stationary contact is carried on an adjustable bracket held by

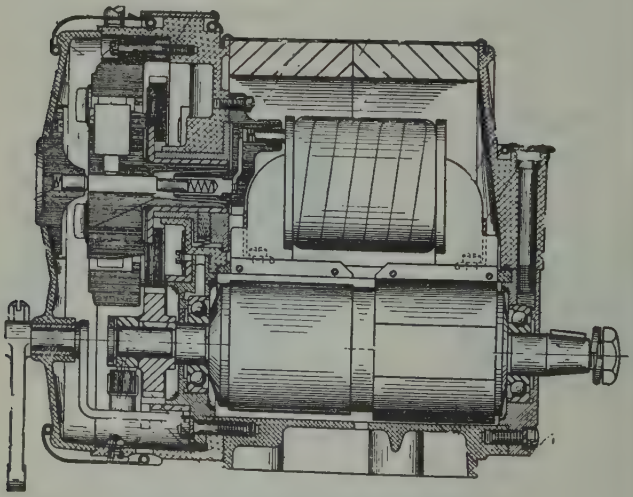


Figure 172.—Side View of Splitdorf Type SS Magneto.

two screws. With these screws loosened, the bracket may be moved to the left to increase the contact gap or to the right to decrease the gap. The condenser is carried on two studs attached to the breaker base. The front cover, carrying the distributor block and the control lever, completely seals the breaker and distributor compartment.

The magnet is held onto the pole pieces by the magneto cover. The positive pole of the magnet is marked in red and the frame is marked in red to correspond. There is a ring safety gap between the secondary winding of the coil and the distributor.

The SS magneto differs from the S type in the construction of the breaker and the location of the condenser, but is otherwise similar as shown in Figures 172 and 173. The condenser in this machine is

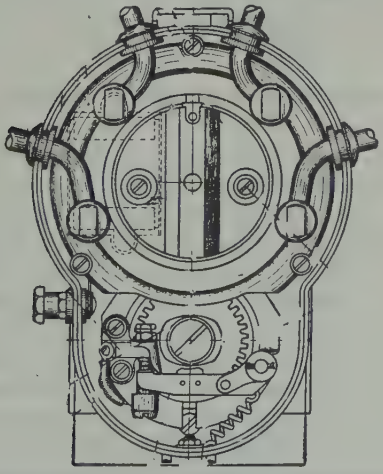


Figure 173.—End View of Splitdorf Type SS Magneto.

attached to the front end plate of the distributor gear. The stationary contact in the breaker is carried on the end of an adjusting screw held by a lock nut, this adjustment being similar to that used in the majority of conventional designs.

The type SS two-spark magneto is shown in Figures 172 and 173. Both ends of the secondary winding are brought out without grounding. One end is taken

through the center of the distributor rotor to one of the two distributor brushes. The other end is taken out through the back of the winding through an insulated hole in the back plate and is carried by a cable around the outside of the magneto to the terminal on the front cover of the distributor block. This terminal connects with the second of the two distributor brushes. Aside from the difference in the high tension connections and the distributor construction, the two-spark machine is like the model SS magneto in all respects.

SPLITDORF TRANSFORMER COIL MAGNETOS

The principles of operation of the Splitdorf instruments are the same as for the other types of transformer coil magnetos, the differences being found in details of construction. The armature is of the usual "H" or shuttle type carrying a single low tension winding one end of which is grounded through a carbon brush passing up through the base plate of the machine and bearing against a ring mounted at the drive end of the armature. The other end of the primary winding is connected with a long screw which passes through the center of the breaker and against the end of which rests a collector brush mounted in the breaker cover. This collector brush it attached to the terminal on the breaker cover and from this terminal a line leads to the low tension winding of the separate coil. This is the terminal which, in the wiring diagrams is marked "A."

The breaker cam with its two lobes is carried by one end of the armature shaft and it actuates a breaker arm which is hinged at one end, has the contacts at the other end and which carries a fibre

roller at its center, the cam lobes operating against this roller. This breaker is so designed that by a change of the cam and of the meshing of the distributor gears it may be used for either direction of rotation. The method of making the change may be understood by reference to Figure 134. The breaker box should be removed, the driven end of the armature shaft held firmly with a pair of pliers and the small nut securing the cam removed. The cam is held with a Woodruff key and may be pulled or pried off. Turn the cam over and replace it the opposite way, then secure it with the nut. Next remove the distributor and the insulated brush that is located at the driving end of the back plate of the magneto; take out the four screws that hold the plate, remove the plate and slide the armature back, bringing the distributor and armature shaft gears out of mesh. Then set the armature back with the gears meshed so that the distributor is in correct relation to the carbon brush and the cam just ready to open the contacts. For right hand rotation, looking from the driven end, the relation of the parts should be as shown in the right hand illustration of Figure 134, while for left hand rotation the relation should be as in the left hand illustration. This illustration also shows the position assumed by the armature core with reference to the pole pieces.

The distributor is of a wipe contact type having a rotating member fixed on the large gear and carrying a T shaped segment, the inner end of which receives the high tension current from a carbon brush whose terminal leads to the coil and whose outer end delivers this current successively to the several carbon brushes which are connected with the spark

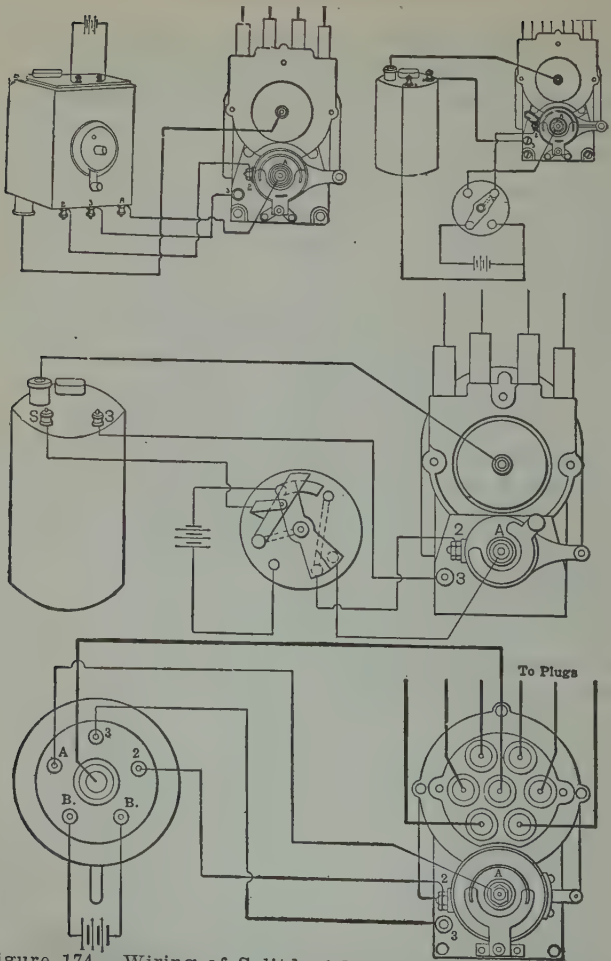


Figure 174.—Wiring of Splitdorf Transformer Coil Magnetos Top: Models "B," "D" and "F." Center: Models "S" and "SS." Bottom: Models "A," "AW," "AX," "B," "D," "F," "O," "S" and "SS" with Dash Switch and Coil.

plugs. All of these brushes are set into the distributor cover.

The coil may be separate and mounted at any convenient place, or it may be in a unit with the switch. In either case a safety spark gap is carried on the coil housing. All of these coils provide separate terminals for both positive and negative sides of the battery and under no circumstances should either pole of the battery be grounded. Typical Splitdorf wiring diagrams are shown in Figure 174.

Timing is done in the usual manner; that is, by bringing the piston of number one cylinder to top center following the compression stroke, turning the armature shaft in its direction of rotation, until the breaker cam is about to separate the contacts, and with the timing lever fully retarded, making the driving connection secure.

In starting the engine on the battery ignition the spark lever should, as in all other similar cases, be fully retarded to avoid dangerous back firing. However, with these types of magnetos in good order, starting may be easily accomplished from the magneto alone by advancing the timing lever from one-half to two-thirds of its travel and cranking smartly for a half or a full turn.

through the center of the distributor rotor to one of the two distributor brushes. The other end is taken out through the back of the winding through an insulated hole in the back plate and is carried by a cable around the outside of the magneto to the terminal on the front cover of the distributor block. This terminal connects with the second of the two distributor brushes. Aside from the difference in the high tension connections and the distributor construction, the two-spark machine is like the model SS.

BREAKER CONTACT GAPS

MAGNETOS

Apollo	
4-cylinder and 6-cylinder	.012″-.015″
Bosch	
Models AT, B, D, DR, DU, NU, ZR	.015″-.016″
Eisemann	
EB, ED, EM, EU	.015″
Dual, magneto breaker	.015″
Dual, battery breaker	.018″
G4, Edit. I and II	.012″-.014″
K-W	
H, HK, T, TK	.015″-.016″
Remy	
S and RD	.025″-.030″
RL	.020″-.025″
P, 30, 31, 32	.018″-.020″
Simms	
SU, C	.015″-.016″
Splitdorf	
Transformer coil types	.020″-.025″
46, 448, 449, 648, 649, Aero and Dixie	.020″
S, SS	.020″-.024″

CHAPTER IX

IGNITION TROUBLES AND REMEDIES

BATTERY SYSTEMS

The parts of the ignition system mentioned in the following list are those in which are most often found troubles that cause faulty operation:

Drive gears or chains	Spark plugs
Breaker and condenser	Battery
Coil and resistance	Switch and fuses
Distributor and safety gap	Wiring

Timing.—The breaker should always be set so that the contacts open at top center or immediately after top center following the compression stroke, with the control in the full retard position. This may be tested by watching the uncovered breaker while slowly cranking the engine with a rod touching the piston.

The adjustment should be made by turning the cam forward just enough to separate the contacts, then turning it slowly back until the contacts just come together. This takes up any play in the drive and the cam should be fastened in this position. The rotor is then replaced and the breaker shaft and cam rocked back and forth as far as the play in the drive will permit. As shown in Figure 175, with the shaft rocked forward the contacts should be held apart; while with the shaft rocked backward the contacts should be closed if the adjustment is correct.

While the majority of breakers are designed so that moving the lever with rotation gives retard and moving it against rotation gives advance, there is a type shown by Figure 176 in which the inner end of the lever engages a pin fastened to the breaker base, the lever being pivoted on the stationary housing. When the outer end of the lever is moved one direction, the lever fulcrums on the pivot and moves the inner end and the breaker base in the opposite direction. With this type of breaker the lever is moved just opposite to usual practice; with rotation for advance and against rotation for retard.

Drive.—The small spiral gears often used to drive breaker shafts may become badly worn or even stripped of some of their teeth. Excessive movement of the breaker cam back and forth with the engine idle indicates trouble of this kind. Driving chains often wear to such an extent that they jump the teeth of their sprockets, allowing the breaker cam to fall back. The ignition is then late and the engine will lack power and pick-up, even if it runs at all. Most chain drives have adjustment for the chain tension, otherwise loose chains will have to be replaced. A chain should have about one-half inch of slack with its sides pressed toward one another midway between the sprockets as in Figure 176.

Some breakers are designed to operate in either direction, while others must be driven a certain way. Sometimes an arrow shows the direction of rotation. The contacts may separate slowly in one direction of rotation and quickly in the other, the latter being correct for running.

Automatic Advance.—There may be excessive play between the driving and driven parts, or the drive

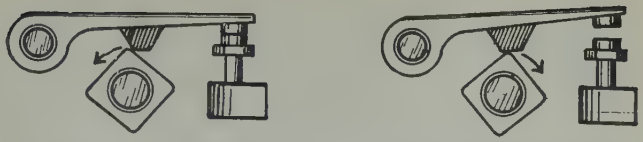


Figure 175.—Test of Breaker Opening by Rocking Cam.

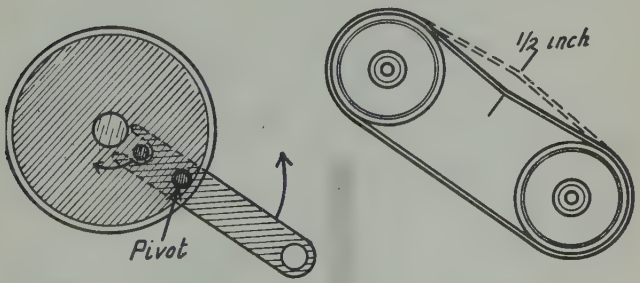


Figure 176.—Pivoted Advance Arm and Slack in Chain.

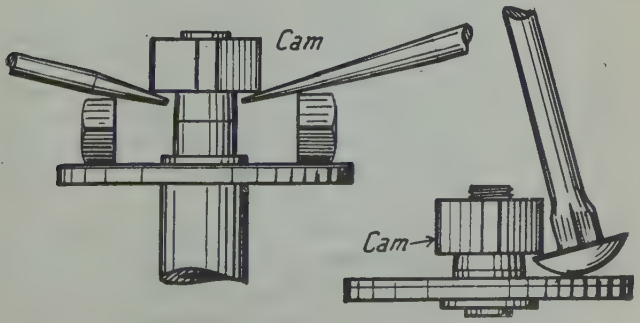


Figure 177.—Lifting Breaker Cam from Shaft.

may fail altogether. Some of these mechanisms are designed to be lubricated, others require no attention of this kind. If those designed for lubrication are allowed to run dry, the parts may stick so that there is a kick-back while cranking if the sticking is in the advance position, or a sluggishness of the engine at all times if the sticking is at retard.

Breaker.—It has already been mentioned that excessive oiling of the breaker is responsible for a great many troubles and for shortening the life of the contacts. The pivot bushing or bearing for the arm should never be oiled, and unless it is known that the cams are designed for the use of oil, lubricant should never be applied to these parts. A sticking breaker arm, due to gummed oil, will cause sparking, pitting and burning of the contacts.

Should it be found that a miss occurs more at low engine speeds than at high and more with a retarded spark than with it advanced, the gap between the contacts when separated should be made greater. If the miss is more pronounced at high speeds or with an advanced spark then the gap should be made smaller. The time of contact and the flow of current through the coil is increased by making the gap smaller and increased by making it larger. A weak battery can oftentimes be used by lessening the gap between the contacts, while current will be economized by making the gap greater.

Before making an adjustment, or assuming that it is necessary, the contacts should be cleaned with gasoline until white. Whenever possible the inspection should be made by removing bodily the parts carrying the contacts rather than by unscrewing the points and thus changing the adjustment. After an

adjustment has been made it will almost always be necessary to clean and dress the contacts so that they come together properly. After they have been dressed, a piece of clean cloth should be drawn between their surfaces to remove any particles of dust or filings. It is essential that the faces of the contacts be brought into line with each other, either by revolving the adjustable point or by bending one of the supports.

In testing the adjustment or gap it should be noted that a certain amount of pitting may prevent the introduction of the thickness gauge, and yet may not be harmful to the operation. If the pits on one contact just correspond with elevations on the opposite contact, the operation will probably be satisfactory and dressing of the surfaces will not be required. Should the contacts be dressed it will not be necessary to completely remove every trace of pitting, for it is impossible to make the operation of dressing provide contact over more than a small percentage of the total area and the hammering action while the breaker is in operation makes a better job than any amount of filing.

It is possible that faulty operation of the breaker is due to breakage or loosening of the spring which operates the arm carrying the movable contact and this point should be examined. It is also possible that the metal of the contact points has been spoiled by allowing the ignition switch to remain turned on with the engine idle and while the breaker is in the closed position. Complete descriptions of the various forms of battery and magneto breakers are given in Chapters II and IV. Note should be taken of the methods of fastening the cams with screws and nuts

and care should be exercised to make these fastenings secure after the cam is timed. With the fastening loosened, the cam may be pried loose from the top of the shaft by placing the points of two screwdrivers on opposite sides as in Figure 177, or by making lifters with hooked ends to go under the cam. It is often possible to use round head carriage bolts of small sizes, catching one edge of the inverted bolt under the cam and carefully prying up at two or three places.

The contact points in most of the new types of equipment are made from tungsten, and when the breaker is operating properly, small particles of this metal will be carried from one contact to the other, sometimes forming a roughness and a dark gray color on their surfaces. This roughness does not in any way affect the proper working of the points because of the fact that the rough surfaces fit perfectly into each other. However, when it becomes necessary to take up the distance between these points due to natural wear, it is usually advisable to remove the contacts from the breakers and with a very fine new file dress down the high spots. This eliminates the possibility of opposite high points touching each other with the new setting and with the the engine at rest.

The tungsten contacts are very hard to file and it is necessary to remove but a very small amount of metal. Although the contacts may be found decidedly rough, if the ignition spark is good it is probable that they are in perfect working condition and no change should be made.

If the breaker arm is grounded with a pig-tail connection, this should be removed before taking the arm out of the housing. The arm is usually held on

its pivot by a small flat spring that may be moved to one side. With coiled breaker springs, the spring will usually come off when the arm is lifted from its pivot, but if flat springs are used their ends are generally held by screws and one end or the other will have to be disconnected before the arm can be lifted out. The stationary contact screw can then be loosened and removed from its support, both contacts then being out where they can be worked upon. After being removed from the breaker, a better job of dressing can usually be done on tungsten contacts by rubbing them on a fine oilstone than by using a file.

Condenser.—Before any condenser tests can be made it will be necessary to disconnect this unit from the breaker, or if it is carried in the coil, to disconnect the coil. The location of condensers and the terminals between which they are connected are shown in Chapters V and VIII. Condenser tests are made by connecting to the terminals for the condenser with these terminals disconnected from everything else.

A short circuited condenser, in which direct current will flow from one terminal through to the other, forms a shunt around the breaker contacts so that the primary circuit is never opened. There will be no spark at the plugs and no flashing at the contacts. A test for this condition is made as in Figure 179 by touching the ends of a circuit tester (with direct current) to the condenser terminals. A flow of current indicates a shorted condenser.

An open circuited condenser or a condenser disconnected from the breaker contacts, allows very severe flashing at the contacts, but there is either a very weak spark or no spark at all at the plugs. A

test for this condition is often made by having two short wires attached to the condenser terminals, touching these wires with the points of a circuit tester carrying direct current, then immediately snapping the ends of the two short wires across each other. If the condenser is in good order, the current from the circuit tester will charge it, and the discharge will then cause a small spark as the two short wires are snapped together. This test must be made very quickly after charging the condenser, otherwise the charge will be lost.

A better test is made by connecting a two-way key type switch and a voltmeter as shown in Figure 179. Moving the switch down charges the condenser, after which it is immediately moved up, connecting the condenser to the voltmeter. If the condenser is in good order, there will be a small reading on the meter. The meter must be sensitive and of the low reading type, having a range not over 15 volts. If there is a small spark between the lower contacts as the key is moved up, the condenser's capacity is probably satisfactory. All condenser tests should be made with direct current. It is very seldom possible to repair a defective condenser, the best way being to replace it with a new one.

Coil.—A preliminary test of a coil may be made by holding a screwdriver or piece of wire against the high tension terminal of the coil and about a quarter inch from the metal of the engine, then opening and closing the breaker contacts with the fingers while the ignition switch is closed. A spark jumping this gap shows the coil to be in good order.

A coil thought to be defective may be tested to the best advantage in connection with a regular battery

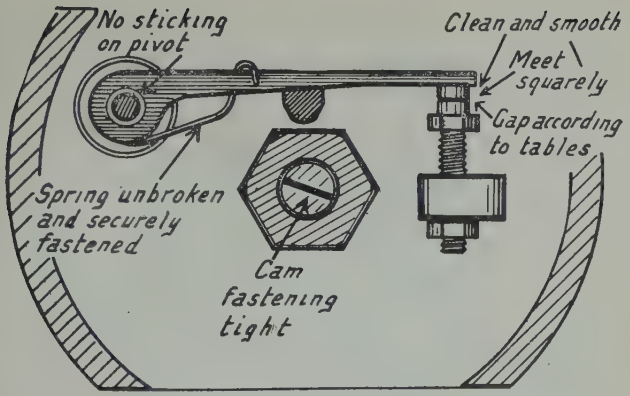


Figure 178.—Troubles in Breaker.

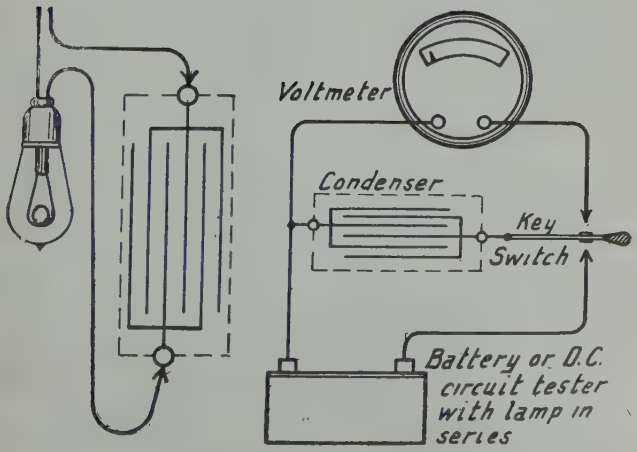


Figure 179.—Testing Condenser with Double Throw Switch.

type breaker and a separate condenser connected as shown in Figure 180. If there is a condenser in the coil, the small condenser switch may be left open, but if the coil contains no condenser, then this switch is closed to connect the test condenser in the circuit.

With the breaker contacts closed and the breaker shaft standing still, there should be a current of 5 to 10 amperes through the primary circuit. A greater current indicates a short circuited primary, while a very small current, or no current, indicates an open circuit or high resistance in the primary. With the breaker running at normal speeds, the primary current should drop to between 1 and 2 amperes.

Coil tests are shown in Figure 181. Tests for open circuits should be made between the two primary coil terminals, also between the high tension terminal and ground. The high tension test must be made with 110-volt or 220-volt current having a lamp in series. The lamp will not light because of the high resistance of the secondary winding, but there will be a flash as the tester points are touched to and removed from the terminals, provided the secondary winding is not open. Tests for accidental grounds should be made with the circuit tester between the metal base of the coil and each of the primary terminals. A very few coils have a grounded primary, but with the majority any flow of current in this test indicates a fault. Should the coil deliver a good spark with the test condenser in use, but fail to do so with its regular condenser, trouble in the regular condenser is indicated. If any amount of coil testing is to be handled, the installation of a tester will be warranted.

Distributor.—Both the inside and outside surfaces of the distributor should be kept clean and free from

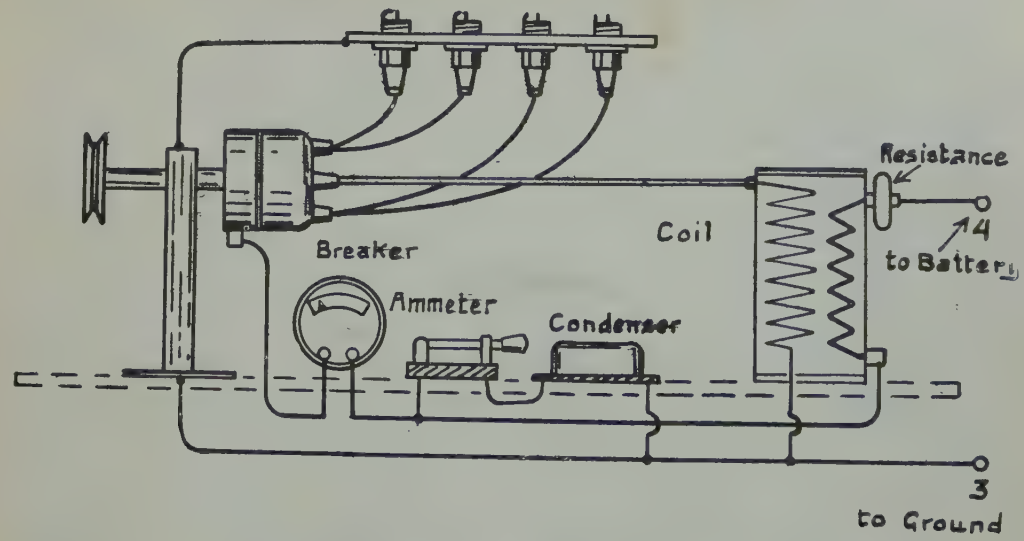


Figure 180.—Connections for Ignition Coil Tester.

oil or dust. Other than this, jump spark distributors require very little care. The gap between the rotor and the pins is from .010″ to .015″. In replacing the distributor cap, care should be used not to bend any of the pins. The spring that provides tension for the center contact with the rotor should have but very slight tension. These points are shown in Figure 182.

The small springs for the brushes in wipe contact distributors require but very little tension, just enough to keep the brush ends on the tracks. Increasing this spring tension will cause excessive wear and will usually burn and blacken the rubbing parts from the friction. The brushes should slide freely in the sockets and they should be pushed out only a short distance by the springs when fully extended. The brushes should be held by the springs so that they cannot fall out of the holders, and the inside end of the spring should be spread enough to keep it in the holder. The brushes should not be jammed into place, and when replacing the distributor cap, care should be used to avoid cramping or binding the brushes. Metal rotor buttons are cleaned and polished by first smoothing with very fine emery cloth, then with crocus cloth, and finally polished by buffing on leather.

If the track followed by the rotor in the cap of a wipe contact distributor has become rough and blackened, it should be rubbed down smooth with fine emery cloth, followed by crocus cloth. Finally a small amount of vaseline is applied with a cloth. These points are shown in Figure 183.

It will be found that practically all rotors will fit on top of their shaft in only one position; being driven through a single pin, by a flat on the shaft, or by some similar device that allows fitting only one

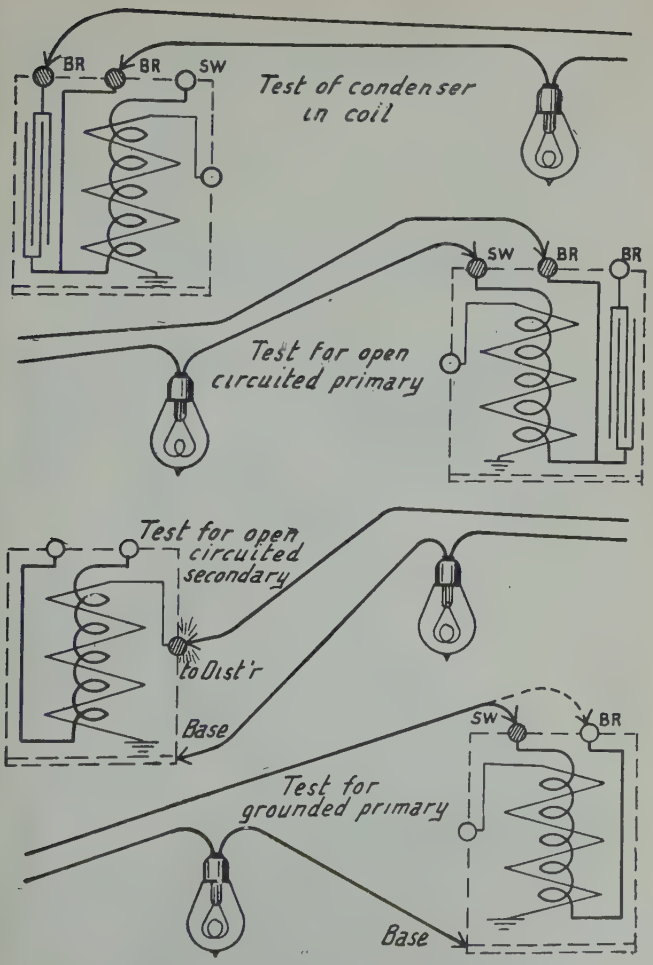


Figure 181.—Tests for Coil Windings.

way so that the firing order is not disturbed by removal and replacement of the rotor. This same thing is true of distributor caps, which fit over a pin or notch at one place, thus insuring their return to the correct position.

It will sometimes be found that almost invisible cracks have developed through the insulation of the rotor or of the distributor cap. The easiest way to test for this trouble is shown in Figure 184. A vibrating ignition coil is grounded to a large metal plate and a length of secondary wire is attached to the high tension terminal of the coil. Passage of battery current through the coil lets a stream of sparks jump from the end of the high tension wire to the plate. With the suspected insulation laid on the plate, the end of the wire may be moved around over the upper surfaces. The spark will jump through any place that may be allowing trouble because of leaking high tension current.

Safety Gap.—The rotor of most battery ignition distributors carries a small metal extension whose end travels within 3/8 of an inch of the shaft or the breaker plate. This forms a safety gap over which high tension current may escape should a spark plug wire come off or should a plug have too wide a gap. This safety gap should never be less than 5/16 of an inch nor more than 3/8 of an inch.

Spark Plugs.—The insulators of spark plugs must be kept clean of soot and oil both inside and outside the combustion space. Two-piece separable plugs are cleaned by removing the core and wiping the insulator with a kerosene moistened cloth or a stiff brush. One-piece plugs may be soaked in kerosene or benzol and then cleaned with a stiff brush. The carbon

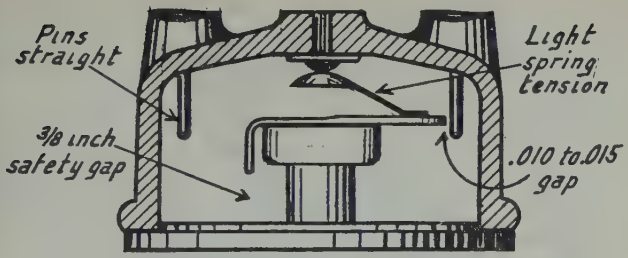


Figure 182.—Troubles in Jump Spark Distributor.

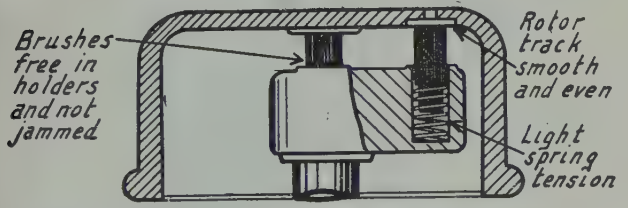


Figure 183.—Troubles in Wipe Contact Distributor.

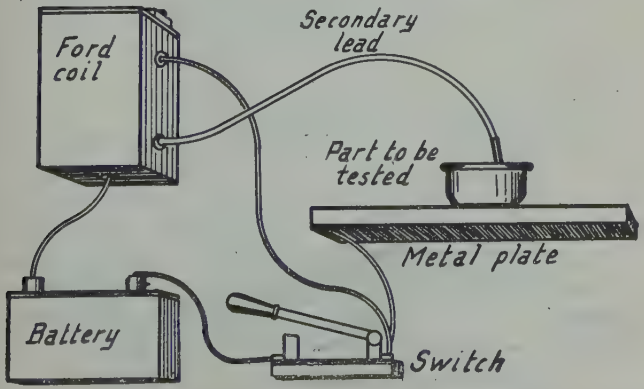


Figure 184.—Insulation Test with Vibrating Coil.

should be scraped from the metal parts and the points between which the spark passes should be kept free from scale and well rounded, not pointed. Oil-soaked mica plugs should be replaced with new ones.

With two-piece plugs the packing nut should be turned down firmly, but not too tightly, because this would crack a porcelain insulator when the plug became hot. Straight thread S. A. E. plugs must always be provided with a gasket in good condition between the shell and the cylinder opening.

The gap between spark plug points should be from 1/50 to 1/32 inch, small for use with magnetos and larger for use with battery systems. If missing occurs mostly at low speed, light loads and small throttle openings, the gap should be made wider. If the missing is more pronounced at heavy loads and open throttle, the gap should be made smaller. A gap too wide sometimes causes popping in the carburetor somewhat similar to that caused by too weak a carburetor mixture. The gap should be altered by bending the electrode fastened to the shell, rather than the central electrode, thus avoiding mechanical strains on the insulator.

The insulation of a plug may be tested by inserting a piece of glass or mica between the points while a spark is passing, as shown at the bottom of Figure 185. Carbon or cracks in the insulator will then let the high tension current go through them in place of passing as a spark around the mica or glass. This tests the plug without taking it apart.

Batteries.—A well charged battery gives better ignition than one partly discharged because the voltage throughout the electrical system is then higher. With a discharged battery an improvement may some-

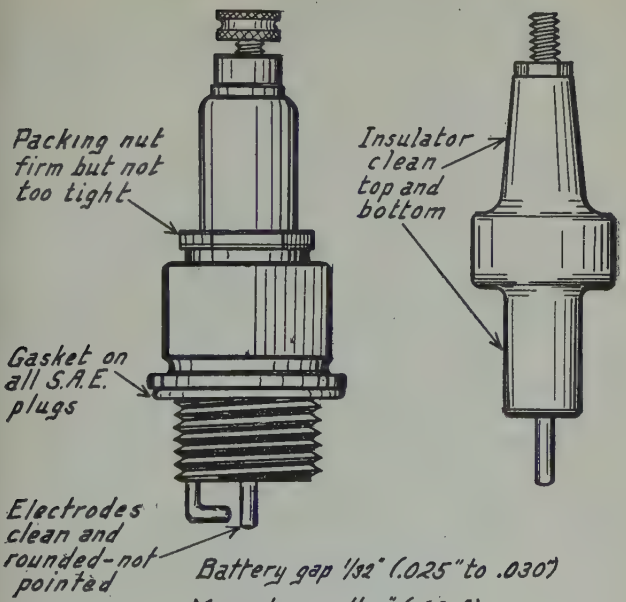

Packing nut firm but not too tight
Insulator clean top and bottom
Gasket on all S.A.E. plugs
Electrodes clean and rounded-not pointed
Battery gap 1/32" (.025" to .030")
Magneto gap 1/50" (.020")
Low speed missing calls for wider gap, high speed missing for smaller gap.
Insulation test with mica or glass between electrodes

Figure 185.—Spark Plug Troubles.

times be made by making a smaller breaker contact gap and a smaller spark plug gap.

Switches and Fuses. — Failure to get current through the ignition contacts of a switch indicates trouble in the contacts, as a general rule. The switch should be opened, the contacts cleaned with fine emery, and if necessary the parts should be bent to provide greater contact pressure. Loose contact parts or terminal studs should be tightened or the parts replaced. Fuses are rarely placed in the ignition circuit, since a stoppage of the engine from a burned-out fuse might come at a very inopportune time, or even at a time that would be dangerous.

Resistance Unit.—The ignition resistance unit may be mounted on the coil or on the breaker, while in exceptional cases it has a separate mounting. This unit should always be in circuit with coils designed for its use. A simple test may be made by turning on the ignition switch and cranking the engine until the breaker contacts close, if they are not already closed. The iron wire should quickly become very hot, even red hot. If the resistance remains cool the primary circuit and the terminal connections of the unit should be checked for a short circuit or an open circuit. If the resistance unit is found to be burned out, a new one should be immediately substituted.

Wiring.—The location of opens, shorts and grounds is treated in Chapter VIII of Part II. It is sometimes possible to locate an ignition short by running the engine in the dark, when a bluish flicker or small spark may be seen. Primary ignition wire does not differ from the kinds of wire used for lighting circuits and is handled in the same way in all cases. Secondary wire simply has more insulation.

It will be found in some cases that the addition of extra equipment has brought about a double ground; that is, the added equipment may have been grounded through the negative side when some other part of the system is already grounded through the positive, or vice versa. In all such cases it will be well to carefully follow the wiring diagram that applies.

It is not best to run several high tension wires through a length of tubing, or to run some of the high tension wires in the same tube with others carrying low tension current because of the induction that may take place from one to another causing a weak spark to occur in the wrong plug and to sometimes have heat enough to ignite the mixture. The high tension line from the coil to the distributor should never be run through a tube with the spark plug lines, but all of these secondary leads should be separated from each other by at least ½ inch of space.

In looking for wiring troubles it should be remembered that if the fault is in but one cylinder, or if it is found in only certain cylinders, the trouble is in the high tension system between the distributor rotor and the cylinder spark plugs of those units that do not operate properly. If the trouble occurs in all cylinders or is irregular in all cylinders the trouble is in the low tension system or in the parts of the secondary system between the distributor rotor and the battery line.

In making an examination of the wiring system the following points should be checked: See that no parts are out of circuit because of loose or broken wires or because of short circuits between terminals, see that no fuses are burned out in case the system contains these members, test the suspected lines for

breaks under the insulation by moving the wire and by bending it back and forth, see that the spark plug wires on a four-cylinder engine are not interchanged between cylinders two and three because of a firing order different from that assumed, and see that the lines between the breaker and the distributor are not longer than necessary.

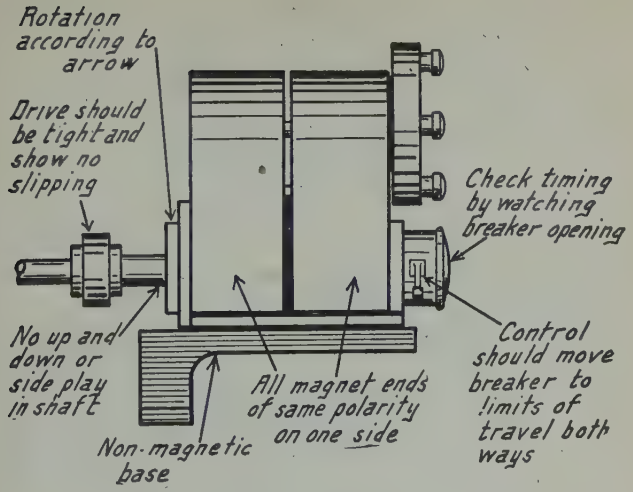
MAGNETO SYSTEMS

The troubles outlined under battery systems for breakers, condensers, distributors and spark plugs apply as well to magneto ignition equipment. There are, however, differences in treatment required by other units of the magneto equipment.

Timing and Drive.—The timing may be checked by placing the controls at full retard and bringing the piston of any cylinder to top dead center following the compression stroke. The breaker contacts should just be opening. The control should be moved from retard to advance, and it should move the breaker arm to the full limit of its travel each direction. Otherwise it will be impossible to get a fully advanced or a fully retarded spark.

The driving connections should be examined for excessive play which will affect the timing, and for slipping couplings or loose set screws allowing the drive to slip back and retard the ignition. Magnetos will operate only when driven in the direction for which they are assembled or designed. This direction is usually marked by an arrow on the end plate or oil well cap at the drive end of the machine.

A magneto should be mounted on a base of non-magnetic material such as aluminum or brass. If carried on a steel or iron base, the base may make a


Rotation according to arrow
Drive should be tight and show no slipping
Check timing by watching breaker opening
No up and down or side play in shaft
Non-magnetic base
All magnet ends of same polarity on one side
Control should move breaker to limits of travel both ways

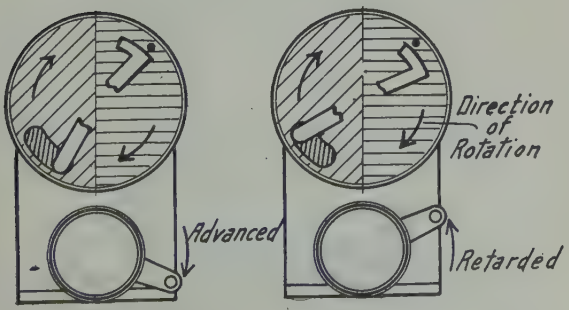


Figure 186.—Magneto Troubles.
Figure 187.—Magneto Distributor Setting.

magnetic path between the magnet poles and prevent the full effect of the field from acting on the armature or rotor. These points are shown in Figure 186.

Breaker.—The setting of the contact gap in magneto breakers is generally much smaller than in battery ignition types, since it is desired to let the primary circuit remain complete until the current builds up to full value. The care of these breakers does not differ in any particulars from that required by the battery types. In fact, many magneto breakers handle battery current under certain conditions of operation for dual systems.

Distributor.—Should the magneto have been taken apart it is advisable to check the timing of the distributor with the armature and breaker as in Figure 187. With the breaker cover and distributor plate removed, and the control fully advanced, the shaft should be turned until the rotor just comes into full contact with one end of the segment or into the pin position. The breaker contacts should be just starting to open. Then, with the distributor turned until the rotor is just leaving contact or leaving the pin position, and with the control fully retarded, the breaker should again just be opening.

The care of magneto distributors, other than their timing, does not differ from that of battery ignition types already described.

Armature.—The primary winding of armature type magnetos is connected between the insulated contact in the breaker and ground as in Figure 188. Tests for open circuits or burned-out coils may be made between these points.

The magneto shaft should be moved up and down, also sideways, and if there is any noticeable play the

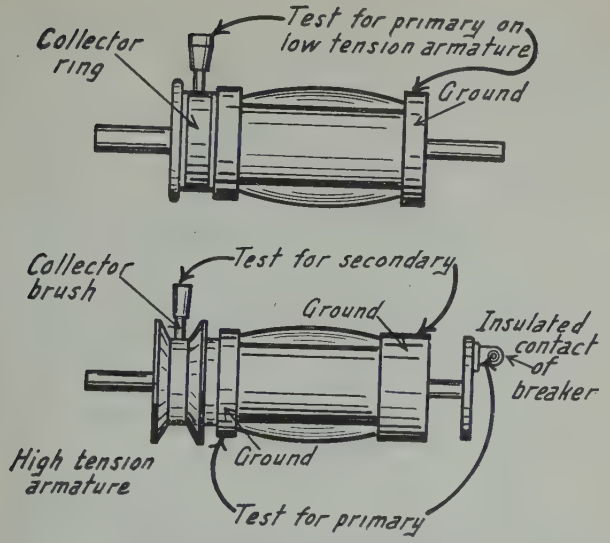


Figure 188.—Tests of Magneto Armature Windings.

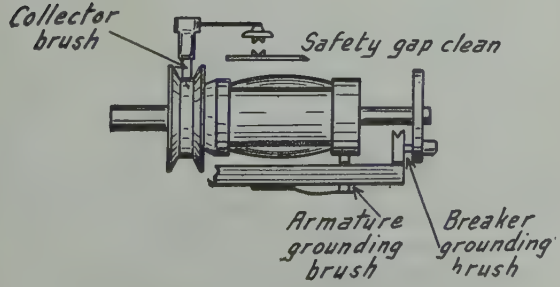


Figure 189.—Location of Magneto Brushes.

bearings should be replaced with new ones. Such play will allow the armature core or the inductors to strike the magnet pole pieces and seriously damage the instrument.

Brushes.—Small carbon or gauze brushes will be found at some or all of the places shown in Figure 189; distributor, armature collector ring, breaker rotating plate, and armature ground to the magneto base. All of these brushes should have moderate spring tension, should be unbroken, and should slide easily in their sockets. The rings or surfaces with which these brushes are in contact should be clean and bright. If found otherwise, they should be dressed with fine emery cloth, then crocus cloth. Care must be used in assembling the magneto parts not to break or chip these small brushes.

Safety Gap.—When located in an exposed position, the space between the safety gap points should be kept clean and dry, and the insulation for the ungrounded point should be clean and unbroken. The passage of a spark at the safety gap always indicates high resistance or an open circuit in the secondary lines, the distributor, or the spark plugs, and the trouble should be located at once.

Inductor Magneto Coils.—The primary and secondary windings of inductor type machines may be removed after taking off the covers or the magnets above them. One end of the primary winding is grounded and the other end leads to the insulated contact of the breaker. The primary and secondary are often in series, and the other end of the secondary then connects with the center of the distributor. These coils may be tested in the same way as described for battery ignition coils.

Magneto Tests.—A magneto should not be tested unless fully assembled because of the danger to insulation of the windings. A simple test of a high tension machine may be made by resting the blade of a screwdriver on a metal portion of the instrument and holding the point about one-quarter inch from the surface of the collector ring while the armature is turned at fair speed. A spark indicates that the primary circuit and parts carrying this circuit are in good order, also that the high tension winding on the armature is working correctly; or, in other words, the trouble, if in the magneto, lies between the collector brush and the spark plug line terminals on the distributor. A weak spark may indicate trouble in the windings, either primary or secondary, in the breaker contacts or insulation, in the high tension connections, or in the magnets.

Magnets.—Care should be exercised in all handling of the magnets. If they are to be taken off the magneto, an iron or steel keeper should be placed between their poles and allowed to remain there until the magnets are replaced. If the armature is removed from the magneto, keepers should likewise be placed between the pole pieces. In replacing magnets on the magneto the workmen should make sure that all negative poles are on one side and all the positives together on the other side, on which side are the negatives, and which the positives being immaterial. If one or more magnets are reversed with reference to the remainder, the magneto will not produce a spark.

Testing and Magnetizing.—Magnets are hard to test with the facilities ordinarily at hand. A magnet of usual size, when properly magnetized, will lift a piece of iron or steel weighing from ten to fifteen pounds.

A small spring balance may be used as shown in Figure 190 and in connection with an iron bar S to test the pull of a magnet. Should the magnet be found very weak it may be put in working condition by means of a remagnetizer such as may be purchased from electrical or automobile supply houses or which may be made as follows:

Two magnet cores, each about five inches high and 1 3/4 inches in diameter should be constructed of clean lengths of iron wire bound together and dipped in solder. These cores should be mounted on an iron base (not one of steel) and should then be covered with a layer of fibre or enameled cambric insulation,

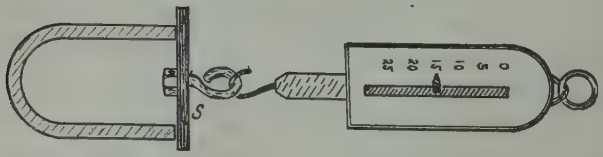


Figure 190.—Testing Strength of Magnets with Spring Balance.

after which they are to be made into electro magnets by winding around each core 500 feet of No. 16 gage insulated copper wire, taking care to have the direction of winding as shown in Figure 191. With this remagnetizer connected to four six volt storage batteries in series, or to any number of batteries providing 24 volts, and with a knife switch in the circuit as shown, the arrangement is ready for use.

The magnet to be charged should be placed on the magnetizer, with the positive pole of the magnet in contact with the negative of the magnetizer, and with the negative of the magnet in contact with the

positive of the magnetizer. The operation is then completed by closing and opening the switch a number of times; or by drawing the magnet away from the magnetizer and replacing it several times, or by tapping the magnet with a small hammer while it is in place on the magnetizer; the idea being to cause a magnetic disturbance sufficient to permanently affect the steel of the magnet.

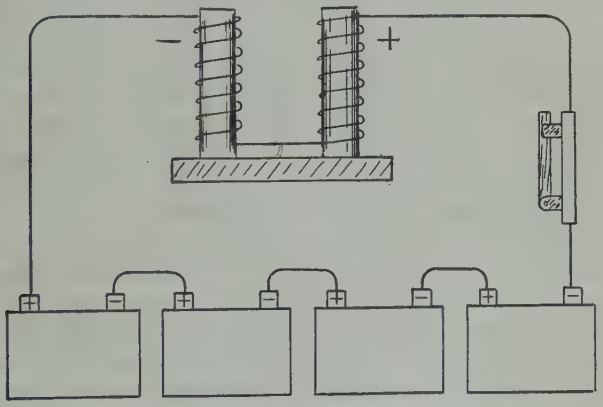


Figure 191.—Construction of Magnet Recharger.

Wiring and Switches.—There is very little to go wrong with the simple grounding switch of a high tension magneto. However, the forms of switch used with some of the dual and duplex magnetos present about the same problems as do the switches used with battery ignition systems and their contacts and terminals may be examined for dirt, looseness, and lack of sufficient pressure.

The low tension wiring seldom includes more than three or four separate wires at most, and their

connections may be traced from the wiring diagrams of the machines being handled. Shorts, grounds and opens are located as usual. The same precautions must be taken with the high tension wires from distributor to plugs and coil to distributor as with the high tension lines of battery systems, all of these problems having been treated.

GENERAL CARE AND MAINTENANCE

Cleanliness.—Dust and dirt, when in combination with a film of oil, form a conducting path through which an escape of secondary current, or even of the primary, may easily take place. It is therefore important for the successful operation of ignition apparatus that strict cleanliness should prevail at all times. The interior of the breaker housing and of the distributor should be kept free from dust, oil and moisture by a frequent use of gasoline, either applied direct or by means of a clean cloth moistened slightly. The use of gasoline is preferable to kerosene because it dries without leaving the film that is left by kerosene. The objection to the use of gasoline is in the danger from fire should any spark occur. It is, therefore, extremely important, when doing this work, that the ignition switch should be open, or in the "Off" position; or, better still, that a wire should be removed from one terminal of the battery and its end taped until the work is completed. If this is not done, and should the primary circuit be completed, an accidental separation of the breaker contact points would probably cause a blaze.

Any foreign substance on the inside or outside surfaces of the distributor housing or of the cap might easily form a conducting path between the various

brushes, pins or segments. Because of the extremely high voltage of the secondary current it will leak across a surface having a very thin film of dirt of any kind and this will cause a peculiar missing and erratic action of the engine.

Space around the terminals of all wires attached to the coil, condenser, resistance unit, breaker, distributor and battery should be kept thoroughly clean. Special care should be given to the top of the storage battery between the terminal posts because a film of the battery electrolyte may easily form at this point due to spilling while testing the gravity or to slight splashing caused by the battery's gassing when fully charged.

It is advisable in all cases to provide a magneto with a leather or oil-proof fabric cover which will shield this instrument against oil from the engine and from moisture and dust. Some of these covers enclose the magneto only, while others are provided with extensions covering the wires between the magneto and the tubes through which the wires pass to the plugs, distributor and other parts of the ignition system.

Rubber thimbles or caps are made which enclose the terminal connections on the distributor and breaker and shields of various forms are made for practically every part of the mechanism which carries ignition current.

The outside surface of the spark plug insulation is oftentimes neglected, and because of the action of the fan in continually blowing a current of dust laden air over the engine, the plugs will finally gather a layer of dirt which will conduct a part or all of the high tension current and thus cause a continuous or

intermittent missing. Porcelain or stone shields are made in forms suitable for placing over the outside of the plug and extending for some little distance over the spark plug end of the wire coming from the distributor. These shields are generally used on motor boat engines which are exposed to the action of the weather.

Lubrication.—Because of the fact that, in most forms of ignition apparatus, lubrication is only called for about once in each thousand miles of running it is usually neglected for much longer times. Such neglect, as it affects the breaker or distributor mechanism, will probably cause no greater damage than a temporary interruption of the operation of these parts. This will bring its own remedy because, until the remedy is applied, the engine will not run. Neglect of bearing lubrication for any length of time will result in ruining the bearings themselves, and very probably in ruining other parts of the mechanism as well, especially if ignition is provided by a magneto.

While some operators give too little lubrication, others give too much by flooding the apparatus when oiling is done, or by too frequent application. Too much oil is one of the most common troubles of the breaker because this oil will finally creep to the contact points where it will cause severe arcing and permanent damage. Oil on these contacts will reduce their useful life to one fourth of its normal length.

A wrong kind or quality of lubricant may also have its effect on the continued operation of the ignition system. Engine cylinder oil is not a suitable form for these delicate parts because of its too heavy body and its tendency to thicken or gum with cold. A

light bodied oil, such as sold for use with sewing machines, will be satisfactory for use in all oil wells and wick oilers and for application to breaker parts when called for. Ball bearings, when exposed for packing, should be filled with vaseline rather than with any form of cup grease such as used at other points about a car.

Many forms of breakers are designed to operate without lubrication in the breaker proper and all breaker oiling other than that done through oil holes leading to the bearings should be done with care and without any excess being applied. Oiling of pivot bearings should be avoided when these parts are provided with fibre or other anti-friction bushings. When required at all, but a very little oil should be applied to the exact point of use by means of a tooth-pick or pointed match. Some breakers are provided with a wick through which the cam surface is kept continually covered with a thin film of oil and the action of others may be assisted by wiping the cam surface with a cloth moistened with light oil.

With a wipe contact distributor having its segments set in a track followed by the rotor brush, this track should be wiped at intervals with a clean cloth slightly moistened with gasoline. After all carbon dust and soot have been removed, the track should be wiped with a cloth having a very light application of vaseline. If the segments are found to be roughened or scored they may be smoothed by rubbing with the finest grade of emery or crocus-cloth. After this operation the track should be polished with a leather pad before lubrication.

All magnetos, and a majority of battery breakers and distributors, are provided with one or more oil

holes from which ducts lead to the shaft bearings and other parts which require lubrication. Specific instructions are generally furnished as to the amount of oil to be given at certain intervals, the requirements usually being from five to ten drops of light machine oil every five hundred to one thousand miles of driving, this oil being placed in each of the openings. The oil holes are generally covered with a spring-closed cap and will be found near the top of the magnet arch, back of the distributor, at either side of the breaker housing and at the drive end of the armature shaft in magnetos. In battery systems oilers are usually found at one side of the driving shaft or at the side of the breaker housing.

Many of these oilers are provided with overflows which carry away any excess of oil that may be applied, provided the overflow tubes are open. Others have no such safety arrangement and with them care must be exercised not to flood the bearings so that the excess of oil will find its way to current carrying parts and contacts.

All control members, such as ball and socket joints, slides, pin bearings, etc., should be examined and oiled frequently so that excessive wear and resultant play may be prevented. Any great looseness that develops in the ignition control parts should be taken up because correct timing of the spark may be seriously interfered with by neglect of this precaution.

In chapters dealing with the details of different types will be found many suggestions as to the proper care of the various makes of ignition equipment, and these paragraphs should be referred to for certain detailed information and exceptions to general rules.

TROUBLES OTHER THAN IGNITION

The ignition system is very often blamed for improper operation of the engine when the real fault lies with some other part of the power plant. Because, as a general rule, ignition devices and the action of the electric current are not well understood, the operator will attempt adjustments and alterations on these parts when they are not required. Should a preliminary test show that a spark is reaching the plugs, nothing further should be done with the electrical parts until consideration has been given to the fuel system and to the valves of the engine.

In case of engine stoppage, or of a failure to start promptly, the driver will naturally make sure that the ignition switch is turned on and that there is a supply of fuel in the tank. Granting that the quantity of fuel is sufficient, it should be seen that the feeding device, either vacuum or pressure system, is operating and sending gasoline to the feed piping. Should it be found, by depressing the priming pin, examining the float bowl or opening a drain cock or plug, that no liquid reaches the carburetor, the fuel lines should be examined for clogging due to some foreign substance or to the fact that a valve may have been closed and not opened before the attempt to start.

Should the fuel reach the carburetor bowl, it is possible that one or more of the adjustments for fuel or auxiliary air may have become improperly set; or, if this is known not to be the case, then it may be possible that the carburetor jet is clogged with some small impurity. Should the engine start and then come to a gradual stop, it indicates that there is some clogging of the fuel lines. If the engine runs with

but little power and with a spitting or popping noise it indicates that the carburetor mixture carries too much air or too little gasoline; while if the engine operates with an intermittent miss in some cylinders or with a galloping action, it indicates that the mixture contains too much gasoline or too little air. It is, of course, not within the province of this book to go into the matter of carburetor adjustment.

Because of the low grade of gasoline now available it is essential that the incoming air for the carburetor, or the fuel itself, be heated in order to produce a satisfactory mixture. Heating of the air supply is the most generally used method and it should be seen that the stove on the exhaust pipe and the tubing from this stove to the air intake of the carburetor are in place and securely fastened. Any valves placed in this air line should also be examined to make sure that they close for choking while starting a cold engine and that they assume a fully opened position with the hand control in the running position.

Valve Troubles.—The engine valves must open and close at the proper time, they must open the correct amount and close promptly and they must make a reasonably gas tight joint with their seats in order to assure correct engine operation.

The kind of engine operation that results from leaky valves may easily be mistaken for ignition trouble, but the valve condition may be readily ascertained by cranking the engine slowly by hand. The degree of compression, or the resistance to turning, should be practically uniform for all cylinders and if the crank can be turned more easily during any one period than during others, it may be assumed that the valves of the cylinder then under compression are

at fault. It will then be best either to open the pet cocks or remove a spark plug from all the cylinders except one and again crank the engine. If considerable resistance is felt, the valves for this cylinder are sufficiently tight and another cylinder should be similarly tested. When one or more cylinders are found with which the compression is poor, the exhaust valves should be removed and examined. Should the exhausts be satisfactory then the inlet valves should be likewise inspected. Rough, pitted or sooted valve faces call for grinding to restore the compression.

During the test of compression it may be advisable, before going on with an examination of the valves, to examine several other points at which the gas may escape. The threads of priming cups, spark plugs and valve caps, also of any cylinder head plugs, should be tested by means of an application of lubricating oil which will bubble during the compression stroke, provided a leak is present. Leaks may also occur between the shell and the core of the spark plug. If the valve condition is good and there are no other outside points of leakage it will only remain to examine the piston rings and should they show signs of blackening or of allowing gas to escape they should be replaced with new ones.

Incorrect valve timing is not a probable trouble unless the engine has been disassembled for repairs. Each maker of engines recommends certain exact settings for the opening and closing of the several valves but unless an instruction book is at hand these settings cannot be known. However, the valve timing may be checked in a general way according to the following principles: Selecting any one cylinder of the engine it will first be necesasry to determine the

point at which the piston reaches top center. The exhaust valve should close either at top center or immediately afterward and as soon as the exhaust has closed, or, in some cases, simultaneously with the closing of the exhaust, the inlet valve should open. With the continued rotation of the flywheel the inlet valve should close at some point within 15 to 30 degrees after the next bottom center has been passed. The flywheel may then be rotated until top center is again reached and after having passed this point the exhaust valve should be found to open a considerable time before the piston reaches the bottom of this stroke.

Should it be found that the valve timing is markedly at variance from the outline given, an adjustment should be made either by means of the tappets or by altering the relative positions or the meshing of the engine timing gears or chains.

The clearance between the end of the valve stems and the part of the operating mechanism which bears against the stems should be correctly adjusted. The space at this point should not exceed the thickness of a sheet of writing paper and should a great excess of clearance be found it may be safely assumed that a correction will result in great improvement of engine operation.

The strength or tension of the valve springs may be either too little or too great. If the springs are too weak it will result in missing at high engine speeds because the valve heads will not be brought to their seats with sufficient speed to correspond with the operating speed of the engine. Weak valve springs may be located by the process of inserting a screw driver blade between the coils of the spring

and then turning the screwdriver so that the spring is compressed. If this results in better operation of the engine the springs should be permanently strengthened either by means of washers placed over the stem at one end or by replacing with a new spring. Should the valve springs be too strong it will result in forming grooves either on the face of the valve, on its seat, or on both. These grooves will prevent prompt seating of the valve and will cause an intermittent missing at practically all engine speeds.

PRELIMINARY TESTS

In order to locate which of the engine cylinders is missing its explosions, the spark plugs should be short circuited, one after another, by means of a wood handled screwdriver or hammer having its metal portion so held that it touches the terminal on top of the spark plug electrode and at the same time touches the metal of the spark plug shell or of the cylinder. This test should be made with the engine running, and if this short circuiting causes a noticeable difference in operation, or slowing of the engine, the plug and high tension line thus being tested is in good order and doing its work. If, however, the short circuiting makes no difference in the engine's operation, then no spark was passing in that plug and the trouble may exist in the plug itself or in any part of the secondary circuit from the plug back to the distributor rotor.

It may be found whether a cylinder is firing by slowly opening its priming or pet cock with the engine running. If a sharp pop or explosion is heard, or if a flame is seen, the cylinder is firing; while if only a hiss is heard, the cylinder is at fault.

Should a miss occur persistently in one certain cylinder, or in a certain two or more cylinders, it may be possible to locate the fault by interchanging some of the parts from the circuit of the troublesome cylinder with similar parts from the circuits of cylinders known to be operating properly. Thus, if the spark plug from a cylinder that is missing be changed for one from a good cylinder, and if the miss then occurs in the cylinder that was formerly in good order and not in the one first in trouble, it is evident that the plug is at fault. Similar interchanges may be made with coils and other units in some systems.

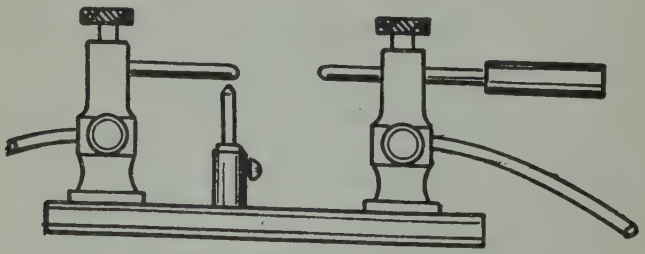


Figure 192.—Spark Gap with Static Point.

The Spark Gap.—The distance that an ignition spark will jump through the air is an indication of its ability to ignite the mixture. In order to be useful for igniting the mixture, a spark should pass through from one-quarter to one-half inch of air space. Such a test may be made by means of the adjustable spark gap. The ends of the high tension circuit are attached to the gap, or, as will generally be the case, either gap end should be grounded to the metal of the car whose ignition is to be tested, and the high tension lead from the coil or from the distributor should be connected

with the other side of the spark gap. With the engine running or being cranked, or with the breaker contacts separated by hand, the spark strength may be tested in a relative way by gradually opening the gap until sparks cease to pass, or, if none pass to start with, by gradually closing it until they do jump the air space. A spark less than one-quarter inch long indicates a secondary voltage that is probably too low to give satisfactory ignition under all conditions of engine speed and load.

SYSTEMATIC TROUBLE LOCATION

The "hit-and-miss" method of looking for ignition trouble is wasteful of time and not productive of satisfactory results. Certain troubles cause certain symptoms which may be recognized. If the connection between symptoms and trouble is known it may be determined much more easily which parts require the attention outlined in this chapter.

In the following outline of troubles these symptoms have been adopted as a guide:

Engine Will Not Start.

Engine Starts Hard.

Certain Cylinders Not Firing.

Irregular Miss in Some Cylinders, But Not All.

Irregular Miss in All Cylinders at All Speeds.

Irregular Miss in All Cylinders at Low Speeds.

Irregular Miss in All Cylinders at High Speeds.

Lack of Power and of Flexibility.

Any case of ignition trouble may be classified as causing some one of these symptoms and each symptom calls for an inspection of certain parts, these parts being listed in the Tables at the left hand side. Below the name of each part is then given a list of the most probable troubles and also suggestions for the work required. This list is not complete because certain troubles are extremely rare, but those given will cover the great majority of all cases presented for solution and will provide a base from which the repair man may work toward the development of his own methods of systematic work.

ENGINE WILL NOT START

Switch—	
Turned off.	
Loose terminal connections.	
Internal open circuits.	Use circuit tester.
Fuel—	
Tank empty.	
Feed lines stopped.	
Fuel feed not working.	
Carburetor jets clogged.	
Fuse—	
Burned out (on grounded battery systems only).	
Battery—	
Run down.	Switch left closed.
Grounded or shorted.	Use circuit tester.
Water level low.	
Dry cell covers broken.	Use wood separators.
Dry cell terminals touching each other or box sides.	Tape if necessary.
Wiring—	
Examine line from coil to distributor center.	
Test primary lines for open, short or grounded circuits, for high resistance and poor connections.	Use circuit tester.
Grounded battery system may have live side also grounded through some of the accessories.	Ground other side of accessory.
Magneto switch line may be grounded.	Remove wire from magneto for test.
Resistance—	
Broken, disconnected or burned out.	See diagrams.
Breaker—	
Arm sticking.	Clean pivot bearing.
Spring loose or broken.	

DRIVE—	
Loose, destroying accuracy of timing.	See instructions for timing.
COIL—	
Disconnected or burned out.	Use circuit tester.
MAGNETO—	
Magnets reversed.	Test polarity.
Ground brush for breaker or armature defective.	

ENGINE STARTS HARD

Battery—	
Run down.	Switch left closed.
Grounded or short circuited.	Use circuit tester.
Water level low.	
Dry cell covers broken.	Use wood separators.
Dry cell terminals touching each other or box sides.	Tape if necessary.
Carburetor—	
Improperly adjusted.	
Breaker—	
Contacts dirty or out of line.	
Arm binding.	
Plugs—	
Dirty, inside or out.	
Gap too wide or too small.	Set 1/32 to 1/64 inch.
Cracked or broken insulation.	
Wiring—	
Dirty or loose terminal contacts.	
Condenser out of circuit.	In case condenser is away from breaker.
Valves—	
Leaking.	Test compression.
Wrongly timed.	
Switch—	
Internal contacts dirty.	Make voltmeter test.
Distributor—	
Dirty, inside or out.	
Magneto—	
Magnets weak.	
Magneto mounted on iron or steel base.	Base must be non-magnetic.

CERTAIN CYLINDERS NOT FIRING

PLUGS—	
Dirty, inside or out.	
Loose or broken insulation.	
Too wide gap.	Set 1/32 to 1/64 inch.
Loose electrode.	
WIRING—	
Spark plug wire broken, disconnected or loose.	
Wires to cylinders 2 and 3 interchanged on four cylinder engine.	Should be placed according to firing order.
DISTRIBUTOR—	
Short circuited through cracked insulation.	

IRREGULAR MISS IN SOME CYLINDERS, BUT NOT IN ALL

Plugs—	
Dirty, inside or out.	
Broken insulation.	
Loose electrode.	
Gap too wide if missing at low speeds.	Set between 1/32 and 1/64 inch.
Gap too small if missing at high speeds.	
Wiring—	
Spark plug wires have poor connections, breaks under insulation or are loose.	
Wire from coil to distributor center in tube with plug wires.	Central high tension line should be separated from others.
Distributor—	
Dirty inside or out.	
Broken insulation.	
Coils—	
Induction from one to another.	Place soft iron sheets between units.

IRREGULAR MISS IN ALL CYLINDERS AT ALL SPEEDS

BREAKER—

- Contacts dirty, pitted, burned or out of line.
- Contact screw or rocker arm loose.

WIRING—

- High tension line from coil to distributor loose or broken. — The only high tension line affecting all cylinders.
- Low tension lines have poor connections, breaks, shorts or accidental grounds. — Will affect all cylinders.
- Distance from breaker to condenser too great. — Should not exceed 36 inches.

DISTRIBUTOR—

- Insulation cracked or broken away at some points.

CONDENSER—

- Out of circuit. — See wiring diagram.

SAFETY GAP—

- Cover dirty or broken.

COLLECTOR RING—

- Dirty or has broken insulation.

COLLECTOR BRUSH—

- Sticking or broken.

MAGNETO ARMATURE—

- Bearings loose.

IRREGULAR MISS IN ALL CYLINDERS AT LOW SPEED ONLY

Breaker—	
Arm sticking.	Clean pivot bearing.
Contact opening too small.	See instructions.
Distributor—	
Timed wrong with armature.	Rotor in wrong position.

IRREGULAR MISS IN ALL CYLINDERS AT HIGH SPEEDS ONLY

Breaker—	
Contact opening too wide.	See instructions.
Distributor—	
Covered with carbon dust or oil film.	
Timed wrong with armature.	Rotor in wrong position.

LACK OF POWER AND OF FLEXIBILITY

Valves—	
Leaking.	Test compression.
Too much clearance.	
Wrongly timed.	
Ignition Timing—	
Wrong setting.	See instructions.
Loose driving parts.	
Magneto Mounting—	
On iron or steel base.	Base should be non-magnetic.

REVIEW OF CHAPTER IX

IGNITION TROUBLES AND REMEDIES

Breaker timing should be such that, with the piston of any cylinder at top center following compression, and with the control retarded, the breaker contacts will open and close as the shaft is rocked back and forth through the play in the drive.

Drive connections should not have excessive play.

Breaker contact gaps should be adjusted according to the settings at the ends of Chapters V and VIII.

Breaker contacts should be dressed smooth with a fine file or oil stone and the supports should be bent to make the contacts meet squarely.

Breaker arms should not stick and the springs must not be broken or loose.

Condenser trouble is indicated by flashing at the breaker contacts with a weak spark at the plugs.

Coil primary windings should be tested for open circuits and accidental grounds. **Secondary windings** should be tested for open circuits. The spark should jump a quarter-inch gap in the open air.

Wipe contact distributors should be clean, should have light tension of their springs, and should have the brush tracks and segments smooth.

Jump spark distributors should be clean and should have no bent or broken pins.

The **safety gap** should be open 3/8 of an inch.

Spark plug insulators should be clean and unbroken; the gap for battery systems should be 1/32 inch and for magnetos 1/50 inch.

Resistance units should heat quickly with the switch closed and the breaker contacts together. Shorted or burned out resistances should be replaced.

Wiring should be checked for poor insulation, shorts, grounds, and open circuits.

Magneto distributors must be set so that the rotor is at one end of the segment with advanced spark and at the other end with retarded spark while the breaker contacts are just opening.

Magneto armature bearings must not allow excessive play in the shaft.

Magneto brushes should be examined at the distributor, back of the breaker, in the base under the armature, and at the collector ring of the armature.

Magneto coils and the windings of inductor magnetos are tested in the same way as battery system coils.

Magneto magnets should be carefully handled and should be placed on the machine with all positive poles on one side and all negatives on the other side.

Oil should be regularly but sparingly applied to all parts of the system designed for lubrication.

Carburetion trouble should not be confused with ignition trouble.

Poor compression makes good running impossible and cannot be remedied by ignition adjustments.

The **missing cylinder** may be located by shorting the spark plugs; no change in engine operation being noted when the plug is shorted in the cylinder in trouble.

ELECTRICAL WORDS AND TERMS

A. C.—An abbreviation for alternating current. See *Current, Alternating.*

Accumulator.—A storage battery. See *Battery, Storage.*

Acid, Battery.—Chemically pure sulphuric acid having a specific gravity of about 1.835, suitable for use in making storage-battery electrolyte for lead cells.

Adapter.—A small threaded sleeve designed to screw into a candelabra base so that a miniature bulb may be used.

Ammeter.—An instrument for measuring the rate of flow of electric current directly in amperes.

Amperage, Constant.—Descriptive of a form of regulation which allows the dynamo current to rise rapidly to a predetermined maximum and then causes the dynamo to maintain this value of current without much rise or fall at all higher speeds.

Ampere.—The unit of current flow. Corresponds to gallons per minute in measurement of water flow. The rate of flow caused to pass through a circuit whose resistance is one ohm by an electrical pressure of one volt.

Ampere-Hour.—The quantity of electric current that flows during one hour through a circuit in which one ampere is passing. Equals 3,600 coulombs. Used in measuring the capacity of storage batteries, in which case a battery having a capacity of 80 ampere-hours would in theory be able to maintain a flow of eight amperes for ten hours, ten amperes for eight hours, or any other combination of hours and amperes which multiplied together will result in eighty.

Ampere Turn.—One complete turn of a conductor in a coil through which one ampere is passing. The amperage multiplied by the number of turns in a coil gives the number of ampere-turns in that coil. The ampere turns of a coil determine its magnetic strength and the same strength

will always be developed by the same number of ampere turns whether they result from a large number of turns and few amperes or large amperage and few turns.

Arc.—The flash or spark between two parts of a conducting path through which current is flowing when these parts are caused to separate. Seen at cut-out contacts, regulator contacts, dynamo and motor brush contacts on their commutators, etc.

Armature.—A piece of iron or steel so placed that it is in the field of a magnet or is acted upon by the lines of force of a magnet.

Armature, Dynamo or Motor.—A part of the machine which consists of an iron core on which are wound coils of wire. In the case of a dynamo, the movement of these coils through the magnetic field causes voltage to be generated and a flow of current to result. In the case of a motor the operating current, or part of it, is sent through the armature windings and the result, together with the effect of the fields, causes the reaction which results in delivery of power from the motor. The armature is usually the part of the machine that revolves, although in some dynamos the armature is stationary and the fields are revolved.

Armature, Drum.—A form of armature in which the windings pass from end to end of the iron core and around the ends. The core is usually of laminated iron of cylindrical shape.

Armature, Magnet.—A small piece of iron or steel mounted on a movable holder and carried near one end of an electromagnet. The armature is attracted to the magnet whenever current flows through the magnet windings. Attached to the movable arms of cut-outs, regulator vibrators, circuit breakers, etc.

Armature Reaction.—A term often used to describe the effect of the rotating armature core in carrying the lines of force of the field part way around in the direction of revolution while the dynamo is in operation. With stationary brushes the voltage between the points on the commutator against which the brushes bear will vary with the extent of this effect present. Utilized in "third brush regulation."

Armature, Ring.—Sometimes called a "Gramme" ring armature. An armature whose windings are placed around a circular or ring-shaped core.

Ballast Coil.—The length of iron wire inserted in the charging circuit of Rushmore and some Bosch-Rushmore dynamos which acts to send a part of the current around the bucking field coil with excessive increase of current generated. Also an ignition resistance.

Bar, Commutator.—See *Segment.*

Battery, Storage.—A number of storage cells placed together as a single unit and arranged to be connected with each other to give the desired voltage for the circuits to which the battery is attached.

Bayonet Type.—A form of lamp bulb socket of cylindrical form and hollow with two or more lengthwise slots open at the lamp end and ending in a turned over or hooked portion of the slot at the other end. The corresponding bulb base carries two or more projecting pins designed to slide down into the slots and then engage with the hooked portions by giving the bulb a part of a turn. The two parts are then held together by the pressure of small plungers or flat springs in the socket portion.

Bendix Drive.—A form of starting motor drive which causes a pinion carried on a threaded shaft attached to the armature shaft to revolve on this threaded shaft and because of its travel along the threads to mesh with teeth on the rim of the engine flywheel so that the power of the starting motor is applied to crank the engine.

Brush.—Pieces of some conducting substance, usually carbon composition or copper, which bear on a moving surface such as a commutator or the segments of a rheostat and which collect or distribute current.

Bucking Coil.—A winding placed on the field magnets of a dynamo and which opposes the strength of the shunt field winding whenever current is passed through the bucking coil. A reversed series coil.

Buckling.—An action that takes place in the plates of a storage cell which causes the entire plate to bend or warp.

Bulb.—The glass part of an incandescent lamp. Often used to designate the glass bulb with the filament and base.

Bus-Bar.—A strip of copper or brass which carries a number of terminals to which conductors and wires of an electric system may be attached.

Cable.—A conducting wire with its insulation. Usually applied to such wires when they are of comparatively large size and made up of many strands.

Calibrate.—To determine the accuracy of the indications given by an electrical instrument such as a voltmeter or ammeter and to note the error, if any, between the scale divisions on the instrument being calibrated and another one of known accuracy or with currents and voltages of known value. Usually employed to designate the operation of correcting the working of an instrument so that its indications are correct.

Candelabra.—The name given to the larger of the two sizes of screw bases used for lamps employed in car lighting.

Candlepower.—The unit used in measuring the light given by any source of illumination. One candlepower is the light given by a standard candle made to burn a certain definite quantity of spermaceti each minute and of standard dimensions and construction.

Capacity, Battery.—The number of ampere-hours discharge that may be secured from a storage battery. It is affected by the rate of discharge in amperes, by the voltage, specific gravity and condition of the plates in the cells, by the temperature of the battery and by many other factors.

Carbon.—A chemical element. Found in graphite, charcoal, diamonds and fuel substances generally.

Cell, Storage.—A unit consisting of several positive plates and several negatives with plates of like polarity connected together and with the whole set immersed in a bath of electrolyte and enclosed by a jar of insulating material. A storage cell gives a voltage of approximately two, regardless of its size, but the capacity depends on the quantity of material in the plates and the design of the battery parts.

Charge.—The action of sending a flow of current through a storage battery so that a chemical change is caused to take place. A quantity of electricity held on the plates of a condenser.

Circuit.—The complete path through which a current flows from the time it leaves the source until it returns to the source. A circuit must always consist of three parts when employed in electrical equipment; namely, the source which may be the dynamo or the battery, the conductors which consist of wires and connections for both positive and negative sides, and the receptive or current-consuming devices which may consist of the lights, starting motor or other equipment. A circuit must always start with and end with the source, and if any portion of the circuit is incomplete there can be no flow of current at any point or in any part of the circuit.

Circuit Breaker.—A device consisting principally of electromagnets and current-carrying contacts which is designed to open a circuit whenever the current flowing through it exceeds a certain value. This name is often applied to a cut-out, although a circuit breaker and a cut-out do not perform similar duties.

Circuit, Closed.—A circuit that is complete from the source to the current-consuming devices and from these devices back to the source and through which a current can flow.

Circuit, Grounded.—A circuit which is completed through the metal work of the car. The metal work takes the place of any other conductor for a certain portion of the path.

Circuit, Open.—A conducting path which is not complete from the source of current to the current-consuming devices and back to the source. No current can flow through a circuit that is open at any point in its path.

Circuit, Short.—A connection between two wires or conductors of opposite polarity that allows the current flowing from the source to complete a path back to the source without going through the current-consuming devices or without doing the work that it should were the current forced to pass through the whole circuit. Should a current-carrying conductor of one polarity come into contact with the frame or metal work of the car when this metal work forms a part of the circuit of opposite polarity from the first conductor, a form of short circuit called a "ground" is formed.

Circular Mil.—The unit used in measuring the cross sectional area of conductors. One mil is one thousandth of an inch and a circular mil is the area of a circle having a diameter of one mil. The circular mil is equal to 0.7854 times the square mil.

Clips, Fuse.—The small spring or screw holders which carry a cartridge fuse.

Clutch, Overrunning.—A device consisting of two parts, one driven from the starting motor and the other driving to the engine to be cranked, with these parts arranged to be held together by wedging rollers when the starting motor drives the engine, but so arranged that the rollers will release and allow the engine to run free when its speed exceeds that at which the starting motor can drive it.

C. O. D. Indicator.—See *Indicator.*

Coil.—One turn or a number of turns of wire surrounding a central core usually of iron or wound on a support that allows a hollow space through the center of the coil.

Commutator.—The series of segments attached to the armature windings of a direct current dynamo or motor and on which the brushes bear. The segments pass underneath the brushes at such a time that the alternating current produced in the armature windings is changed into a direct current for use in the outside circuits.

Compound Winding.—See *Winding, Compound.*

Condenser.—A number of sheets of some thin conductor, usually tin foil, placed one on top of another but separated by some insulating material such as mica or waxed paper. The sheets of conductor are connected in two sets, every alternate sheet being fastened to one lead and those between to the other lead. The condenser is placed so that one lead attaches to one current-breaking contact while the other lead attaches to the other contact. A part of the electricity that would ordinarily result in a spark at the time the contacts separate, passes into the condenser and remains there until allowed to escape through conductors attached to the condenser terminals. This electricity is said to form the condenser's charge.

Conductor.—Any material or substance through which the electric current can pass with ease. All metals and many liquids are good conductors.

Conductivity.—The opposite of resistance. A measure of the readiness or ease with which current can pass through a conductor. The higher the resistance to passage of current becomes, the less will the conductivity become.

Conduit.—A tubular protecting covering for electric wiring generally made from metal and either flexible or rigid.

Connector.—A device for completing one or both sides of a circuit by means of pin plungers carried by one part of the connector and designed to fit into holes in the other part of the device. The ends of the circuit wires are fastened to the pin at one side and to the metal lining of the hole at the other.

Constant Amperage or Voltage.—See *Amperage, Constant*, and *Voltage, Constant.*

Contacts.—Small pieces of heat and spark-resisting conductor, usually metal or carbon, that carry the current flowing through a circuit when two of the contacts are touching each other and which act to break the circuit when they are drawn apart.

Control.—The action of limiting the current delivered from a dynamo and of preventing the current in the charging circuits from taking improper paths. Control is effected by the current regulating system and by the cut-out.

Controller.—An electromagnetic cut-out and a current output or voltage regulating device carried in one case or combined with each other so that some of their parts function with both units.

Core.—The iron form upon which coils of wire are carried or wound in forming electromagnets, dynamo or motor field magnets, armatures, etc.

Corrosion.—The action of acids or alkalies upon metal or the substance formed by this action. Found on the terminal connections of storage batteries and between the metal of their grids and the active material of the plates.

Coulomb.—A unit which measures electrical quantity and whose value is 1/3600 of an ampere-hour. A coulomb is the quantity of electricity that passes through a circuit in one second if the rate of flow is one ampere.

Current.—The rate of flow or the quantity of electricity that is passing through a circuit. Current flow is meas-

ured in amperes and is increased with increase of pressure or voltage and is decreased by increase of resistance.

Current, Alternating.—A current which reverses its direction of flow or its polarity at regular intervals. Alternating current is generated by all dynamos and in direct current dynamos the alternating current is changed to direct current by the commutator.

Current, Continuous.—Direct Current (which see).

Current, Direct.—A current which always flows in the same direction through its circuit and which would cause conductors through which it flows to remain of the same polarity at all times.

Current, Eddy.—Currents produced in the iron cores of the armature and field magnets of motors and dynamos by the motion of these parts in a magnetic field or by the motion of magnetic lines of force about them.

Current, Pulsating.—A current whose value rises and falls suddenly.

Cut-in.—The closing of the charging circuit by the cut-out when its contacts come together. Cut-in time means the engine or armature speed at which this action takes place.

Cut-out.—A switch through which the charging circuit from dynamo to battery is completed. When the cut-out is open there can be no flow through the charging circuit, either from dynamo to battery or from the battery through the dynamo. When the cut-out is closed a current may flow in either direction and the direction of flow will be from the unit having the higher voltage to the one of lower voltage.

Cut-out, Electromagnetic.—A cut-out switch whose current-carrying contacts are closed by the magnetic strength of an electromagnet through the windings of which current flows from the dynamo and whose strength is determined by the voltage generated by the dynamo. The contacts are opened and held open by the action of a spring whose tension controls the action.

Cut-out, Hand or Manual.—A cut-out switch operated by the driver of the car and so connected with either the ignition or starting switches that the cut-out will be open whenever the engine is idle or the ignition turned off and

will be closed by the closing of the starting switch or by the closing or turning on of the ignition switch.

D. C.—Direct Current. See *Current, Direct.*

Discharge.—The flow of current from a storage battery to and through the outside circuits. Any flow which causes the capacity of the battery to decrease. Any flow whose direction is away from the positive terminals of the battery and into the negative.

Distribution Panel.—See *Panel, Distribution.*

Double Contact.—A name descriptive of a lamp bulb whose base carries two metallic points through which current enters and leaves the bulb. Also applied to a base designed to receive such a bulb.

Double Deck.—A motor and a dynamo which form separate units electrically but which are mechanically fastened together with one above the other either in one housing or in separate cases.

Double Wire.—See *Two-Wire System.*

Dynamo.—An electric machine which changes mechanical power into electric current.

Ediswan.—See *Bayonet.*

Efficiency.—The amount of useful work or power that may be taken from a device in proportion to the power or work of some other form that is consumed by the device while working. The efficiency of a storage battery is the discharge in ampere-hours or watt-hours that may be secured in comparison with the ampere or watt-hours of charge that is given. The efficiency of a dynamo is the percentage of current that it delivers in proportion to the power it requires to drive the dynamo while delivering that current. The efficiency of an electric motor is the percentage of power delivered in proportion to the flow and pressure of electricity that the motor requires in order to deliver that power.

Electricity.—The name given to the cause of electrical effects of all kinds.

Electromagnet.—A magnet made from a core of soft iron and magnetized by the passage of a current of electricity through a coil of wire surrounding the core.

Electromotive Force.—Electrical pressure, potential or voltage. Ability to do work.

Energize.—In speaking of a coil or magnet this means that the coil or magnet receives current and produces magnetism.

Faure Plate.—A pasted plate for a storage battery. See *Plate, Pasted.*

Field.—The space around the poles of a magnet through which the magnetism or magnetic lines of force of the magnet will produce certain effects is called the field of the magnet. As the word is ordinarily used it means the field winding or the field winding and magnet core of a dynamo or motor.

Filament.—The conductor carried inside of the bulb of a lamp and which gives light when heated to incandescence by the passage of current against its resistance and through its length.

Finish Rate.—The number of amperes that may safely be passed through a storage battery for a period of from eight to twenty-four hours in completely charging the cells. Same as twenty-four rate. Depends on the ampere-hour capacity of the battery and is usually a number of amperes that corresponds to about one-twentieth of the ampere-hour capacity.

Floating.—Placing a battery in a lighting and starting system so that one side of the circuit includes and attaches to the positive terminal of the battery, of the dynamo, of the lamps and of the starting motor, and so that the other side of the circuit attaches to the negative terminals of these units. The battery may then receive current from the dynamo when the dynamo output is above the current required by the lamps, etc., and will give the required additional amount of current to the circuit whenever the dynamo output is less than the requirements of the current-consuming devices. The battery acts as a reservoir into which any excess current passes and from which any deficiency may be drawn.

Foot Pound.—See *Pound, Foot.*

Formed.—The condition of storage battery plates after the material in their plates has been changed to peroxide of lead for the positive and to sponge lead for the negative by the passage of a charging current and by intervening

discharges sufficient in number and time to produce this effect.

Fuse.—A short length of wire of various compositions which is so proportioned and made that it will carry any amperage up to a certain predetermined maximum, but will heat to the melting point and separate when this current is exceeded, thus breaking the circuit protected by the fuse.

Fuse, Cartridge.—A fuse enclosed in a tube, generally made from fibre or glass and capped with metal at each end so that when placed in fuse clips the current may pass from the clips through the caps and through the fuse. Used when it is desired to avoid a spark in the open air.

Fuse, Field.—A fuse placed in the circuit of the field windings of a dynamo and of such a capacity that it will melt and open the field circuit when the amperage reaches a point beyond which there would be danger of burning out the field windings themselves.

Fuse, Link.—An unenclosed fuse wire.

Gap, Air.—The distance between the end or pole of a magnet and the iron of the magnet's armature which may be the iron of the dynamo or motor armature core or the armature piece of an electromagnet.

Gassing.—The evolution of hydrogen and oxygen gases from the water in the electrolyte of a storage cell caused by the passage of charging current through the cell.

Generator.—An electric machine by means of which mechanical power is made to produce electrical energy, or electromotive force, which may be used to cause a flow of current through circuits connected to the generator. The generator includes a rotating armature and stationary field in the forms used for starting and lighting. It generates electrical energy by using the principle of electromagnetic induction.

Gramme Ring Armature.—See *Armature, Ring.*

Gravity.—See *Specific Gravity.*

Grid.—The metallic framework which supports the active material and which with the active material forms a plate of a storage cell.

Ground.—The name applied to the metal parts of a car. The "ground" or metal is used to complete one side of

the circuits in a one-wire system. Whenever a conductor or an electrical device is in metallic and electrical connection with the metal parts of the car the conductor or device is said to be "grounded" to the part on which it attaches or is mounted. See also, Circuit, Grounded and Circuit, Short.

Ground Return.—A name applied to a one-wire system or a system in which a part of either the positive or negative side of some or all of the circuits is completed through the metal work of the car.

Holder, Brush.—The part of a dynamo, motor, rheostat, etc., to which the brushes are fastened or in which the brushes are carried. The holder may be rigidly mounted or may be carried on pivot bearings.

Horsepower.—The rate at which work is done when 33,000 pounds is raised to a height of one foot in one minute. Provided this amount of work has been done in one minute one horsepower is being expended. To do the same amount of work in one-half the time would require twice the mechanical power or two horsepower of effort although the total amount of work done would remain the same. An electrical horsepower equals 746 watts. The horsepower that a current is capable of developing may be found by multiplying the number of volts by the number of amperes to find the number of watts and then by dividing this number of watts by 746, which will give the number of horsepower or the fraction of one horsepower.

Hydrometer.—A device for finding the weight of a liquid in relation to the weight of water. The usual form of hydrometer consists of a glass tube weighted at the lower end, having an air bulb above the weight and carrying a thin extension or tube above the air bulb. The hydrometer will sink into any liquid to a point on the extended tube or stem that corresponds to the weight of that liquid. The stem is graduated according to the specific gravity scale which assumes water to be unity and represented by 1.000. A liquid twice as heavy as water would then have a specific gravity of 2.000, etc. The point on the scale carried by the stem to which the hydrometer sinks indicates the weight or specific gravity of the liquid in which it is floating. See *Specific Gravity.*

Hydrometer Syringe.—A glass tube containing a hydrometer and into which a liquid to be tested may be drawn through a nozzle at the lower end of the tube. The upper end of the tube carries a rubber bulb which may be compressed to afford the suction necessary in drawing liquid into the tube.

Ignition.—The action of setting fire to the combustible fuel mixture in the cylinder of an engine. In automobile work, ignition is caused by an electric spark passing between two electrodes of a spark plug, this being called jump spark ignition. The sparking current has a pressure of 6,000 to 12,000 volts in most cases and is produced from low voltage current by induction in a coil. The ignition system includes all the parts using battery current for ignition purposes, and sometimes a magneto for the production of the ignition current.

Ignition-Generator.—A generator carrying an ignition breaker and distributor on its shaft.

Induction.—The production of electromotive force by the movement of conductors through lines of force or by change of lines of force through conductors. Self-induction acts to produce a second E. M. F. in a conductor carrying a primary current. Mutual induction allows the effect of one conductor to produce an E. M. F. in another. Electromagnetic induction produces an E. M. F. in a conductor by relative movement between the conductor and a magnetic field or lines of force. Induction is utilized in armatures, ignition coils, etc.

Inertia Pinion.—A starting motor drive operating on the same principle as the Bendix Drive, which see.

Inherent.—Some effect in a machine that is a natural result of the design and construction used in the machine and that does not require the use of external or additional moving parts to accomplish the result. Used to describe certain forms of regulation, especially reversed series systems in which it is the direction of winding the series coil that produces the inherent regulation.

Insulated Return.—A name applied to a one-wire system, which see.

Insulation.—Material that is a non-conductor of electricity and that is used in connection with conductors to prevent

current passing from the conductor at any point where such passage is not desired.

Iron Wire Control.—A system of regulation used with Rushmore and some Bosch-Rushmore dynamos by which a length of iron wire is made to send current through a bucking field coil by the heating of the iron with passage of excessive current through it.

Jar, Battery.—A receptacle made from a material that will carry liquids without leakage and which is an electrical insulator. The plates and electrolyte of storage cells are placed in the jar.

Junction.—A terminal connection, often enclosed, at which a circuit divides into two or more parts.

Keeper, Magnet.—A small piece of iron or steel placed across the poles or ends of a permanent magnet and affording a path through which the magnetic circuit may be completed.

Kilowatt.—One thousand watts. Approximately 1⅓ horsepower.

Lead, Peroxide of.—The chemical substance formed by the combination of one part of metallic lead with two parts of oxygen.

Lead, Sponge.—Pure metallic lead of a porous or spongy form.

Lead, Sulphate of.—The chemical substance formed by the combination of one part of metallic lead with one part of sulphur and four parts of oxygen.

Lines of Force.—The paths taken by the magnetism around the poles and in the fields of magnets.

Load.—The resistance placed in a circuit and through which current passing in that circuit must flow. The load may take the form of lamps, starting motor or any other current-consuming device.

Magnet.—A material possessing the power of attracting other magnetic bodies or iron and steel. A material having a field of magnetic lines of force. For practical purposes magnets may be made only from iron or steel.

Magnet, Compound.—Magnets with like poles together.

Magnet, Permanent.—A magnet of hard steel which retains magnetism for long periods of time.

Magnetic Lines of Force.—See *Lines of Force.*

Magnetism.—The cause of all magnetic effects and actions in magnets or magnetic materials.

Magnetism, Residual.—Magnetism remaining in soft iron that has once been magnetized.

Magneto.—An electric machine using electromagnetic induction to produce an alternating current suitable for ignition work. The generated current is stepped up to a high sparking voltage by an induction coil on the armature or separate from the magneto.

Manual Cut-out.—See *Cut-out, Hand or Manual.*

Marker Bulb.—A small bulb carried by one of the large lamps of a car but outside of the focal point of the reflector. Also called pilot or dimmer bulbs.

Material, Active.—The paste formed from compounds of lead mixed with dilute sulphuric acid which is used to fill the grids of storage cells in making plates.

Mercury Well.—A voltage regulator used with some types of Delco equipment in which a resistance in the field circuit is more or less short-circuited by a bath of mercury.

Meter, Ampere-Hour.—A device that measures and indicates the quantity of electric current passing into or out of the storage battery. Used in connection with the regulating system of some Delco equipments.

Miniature.—The smallest size of screw base for incandescent lamps.

Motor.—An electric machine that changes electric current into mechanical power.

Motor-Dynamo.—An electric machine having one armature core with either one or two windings; one or two commutators and one set of field cores with two or more windings, which acts either as a dynamo or motor, according to whether it is supplied with power or electric current.

Multiple.—A form of circuit in which two or more sources of current or two or more current-consuming devices have their positive terminals connected together and their negatives connected together.

Negative.—See *Polarity.*

Neutral Wire.—A wire connected to each of two sources of current, either batteries or dynamos, so that current may flow in either direction through the wire according

to which one of the two sources is being drawn upon for the greater amount of current. When the load is evenly divided between each source the neutral wire carries no current.

Nitrogen Bulb.—An incandescent lamp bulb in which the air has been replaced by the gas nitrogen.

Ohm.—The unit of the resistance to the passage of electricity. An ohm is the resistance that will allow one ampere of current to flow in a circuit when the pressure is one volt.

Ohm's Law.—The relation between electrical pressure, current flow and resistance is expressed by Ohm's Law as follows: The current or amperage equals the voltage divided by the resistance in ohms; the voltage equals the amperes of current multiplied by the resistance in ohms; the resistance may be found in ohms by dividing the voltage by the current in amperes. When C represents amperes, E represents volts and R represents ohms, the law may be expressed by the equations:

$$C = \frac{E}{R} \qquad E = C \times R \qquad R = \frac{E}{C}$$

One-Unit System.—An electric starting, lighting and ignition installation in which an ignition breaker and distributor is combined with a motor-dynamo thus allowing one unit to perform the three functions of lighting, starting and ignition.

One-Wire System.—A method of connection in which one side, either positive or negative, of all or part of the electrical devices and conductors is attached to the metal or ground of the car and in which the metal is used as a conductor to complete these circuits.

Open.—See *Circuit, Open.*

Output.—The number of amperes or the number of watts furnished by an electrical source such as a dynamo or battery.

Overrunning Clutch.—See *Clutch, Overrunning.*

Panel, Distribution.—A body or plate of insulating material to which lead the conductors for several circuits and

which carries suitable terminal connections and suitable internal and external wiring to allow the circuits to be completed in their proper paths. Used to centralize the wiring and connections of the electrical system.

Parabolic Reflector.—A reflector whose surface is so shaped that a section cutting from side to side and through the center would form a parabola. This form causes the light reflected from a source of illumination placed in the focus of the parabola to be thrown in parallel rays and straight ahead in the direction of the axis of the parabola.

Parallel.—See *Multiple.*

Paste, Battery Plate.—The filling for the grids of storage cell plates. See *Material, Active.*

Peroxide of Lead.—See *Lead, Peroxide of.*

Pig-Tail.—A short flexible wire that forms the electrical connection between a brush and the conductor that carries current to or from the brush.

Pilot Lamp.—A lamp placed in a charging circuit in such a way that it lights when the cut-out closes and remains lighted while the cut-out remains closed. Also used to designate a Marker Bulb, which see.

Pinion.—The smaller of two toothed wheels which are in mesh. The larger one is called the gear.

Plate, Battery.—One of the units entering into a storage battery cell. The plate is formed of a metal framework or grid whose spaces are filled with active material formed from a paste of compounds of lead mixed with dilute sulphuric acid. After forming, the material of the positive plate is peroxide of lead and that of the negative plate is sponge lead.

Plate, Pasted.—A plate conforming to the foregoing definition of Battery Plate as distinguished from plates formed from pure metallic lead which has been acted upon by the passage of charging current to change the surfaces into peroxide of lead and sponge lead for the positive and negative respectively. Sometimes called a Faure plate from the name of its inventor.

Plug, Vent.—A small screw or clamping plug placed in the opening of each cell of a battery and by means of openings in which the gases evolved during charging may escape.

Plug, Spark.—A device screwed into the cylinder wall of an engine, and through an insulator in which are carried electrodes forming conductors for the secondary or sparking current. The spark is formed at a gap between the electrode ends inside the combustion space of the cylinder carrying the plug.

Spark plug electrodes are made of nickel steel in most cases, and the insulators are formed of porcelain, of mica, or of artificial stone. These parts are carried in the threaded shell. Two threads are in common use; the one called the S. A. E. thread being straight; the other being a standard half-inch tapered pipe thread.

Point.—One thousandth part of a specific gravity unit, or 0.001. The difference between a specific gravity of 1.251 and of 1.252 is one point, between 1.250 and 1.275 is twenty-five points, etc.

Polarity.—The relative value of electrical pressures when considered with reference to the earth as having zero pressure. Points having pressure higher than that of the earth are said to be of positive polarity; those having less pressure are said to be of negative polarity. Polarity indicates the direction of current flow through conductors from higher to lower pressures.

Polarity may also refer to the direction of flow of magnetic lines of force; these lines issuing from a magnet pole of positive polarity and entering a magnet pole of negative polarity, the flow through the magnetic field being from a positive pole to a negative.

In the case of a source of electricity, the terminal or end from which current is supposed to flow is called the positive terminal, while the terminal into which current flows is called the negative. Current flow is always from positive to negative and from a higher voltage to a lower.

Wires attached to a positive terminal are called positive wires until they reach the current-consuming device or the outer end of the circuit. Wires from the consuming-device to the source and attaching to the negative terminal at the source are called negative wires.

Magnetic polarity is used to distinguish the ends or poles of a magnet and is determined according to the direction of movement of the magnetic lines of force. The pole

from which the lines of force leave the body of the magnet is called the positive or North pole and is designated by a plus sign, +. The pole at which the lines of force reenter the body of the magnet is called the negative or South pole and is designated by the minus sign, —.

Pole, Dynamo or Motor.—The ends of the field magnet cores that are presented to the armature and which form the walls of the armature tunnel. An electric machine having two field magnet cores is called a two-pole machine, one with four magnet cores or fields is called a four-pole machine, and so on, for any number.

Pole, Consequent.—A magnet pole formed when two ends of the same polarity, either positive or negative, are placed together, or a pole formed when two windings act to produce like poles at some point in a piece of iron located between the windings. In the case of a dynamo or motor the iron at the consequent pole is shaped to form a part of the armature tunnel but carries no windings.

Pole Piece.—A piece of iron or mild steel fastened to the end of a field magnet core and so shaped on its armature side as to form the curve of the armature tunnel.

Positive.—See *Polarity.*

Potential.—A term having the same meaning as voltage or electromotive force. The difference of electrical pressure between two points is their difference in potential. Potential is measured in volts.

Pound, Foot.—The work required to raise a weight of one pound to a height of one foot.

Pressure, Electrical.—The force that acts to send current through a circuit against the resistance of the circuit. Also called Potential and Electromotive Force. Measured in Volts.

Primary.—The winding of a transformer or ignition coil that receives the current from the battery or dynamo at low voltage and through the action of which on a magnetic core is produced the current of high voltage used for ignition. The wiring of the ignition circuits through which current of low voltage passes is called the primary wiring. A primary cell or battery is one which produces electric current by chemical action and in which this action can not be reversed as it can be in the storage cell.

Rectifier.—A device which changes an alternating current to a direct current.

Regulation.—The action of limiting or controlling the amperage, or voltage, or both amperage and voltage, of a dynamo.

Relay.—A device which closes or opens a circuit when the voltage or amperage rises to a certain value in a second circuit. A relay consists of an electromagnet through whose windings flows the current that controls the action of the relay and the time at which it will close a circuit, or open a circuit depending on its construction. When the relay is designed to close a circuit the armature of its magnet brings a movable contact to a stationary one and the circuit to be closed is completed through these contacts. When the relay is designed to open a circuit the movable and stationary contacts are so placed in relation to each other that movement of the relay magnet armature draws the contacts apart and opens a circuit that has been completed through the contacts. The word relay is often used to designate a cut-out or a regulator when these devices are electromagnetically operated.

Resistance. — That quality of a material by which it opposes free passage of the electric current through the material. Measured in Ohms, which see.

Reversed Series. — A generator series winding through which charging current flows in a direction that opposes the effect of the shunt field and forms a means of regulating the generator output.

Rheostat.—A resistance whose effective value may be adjusted manually or automatically.

Secondary.—Windings, conductors, or other parts in which electromotive force is produced by mutual induction from similar parts in a primary circuit. The secondary, in automotive work, is of higher voltage than the primary. In ignition work the secondary circuit carries the sparking current, or high tension current.

Segment.—A contact piece against which the brush of a motor, a generator or a rheostat bears and to which is attached one or more wires from the windings or the resistances of these units.

Separator.—A sheet of insulating material, usually formed from specially prepared wood or hard rubber, which is used between adjoining plates in a storage cell so that these plates may not come into electrical connection with each other. Also called an insulator.

Series.—A connection of conductors made between several sources of current or between several current consuming devices in such a way that all of the current that passes through any one unit or conductor will also have to pass through every other unit and conductor in the series circuit. In the case of units having terminals of definite polarity the positive of one will be connected with the negative of the next one in the circuit and the positive of this second unit with the negative of the third, etc. See also Winding, Series.

S. G.—An abbreviation for *Specific Gravity,* which see.

Short.—See *Circuit, Short.*

Shunt.—A path of a circuit through which only a part of the whole current flows, the balance passing through one or more additional paths whose ends attach to the same source. When two conductors or two current-carrying devices are attached to a source of current so that there is a direct metallic path from each conductor or each device to each terminal, positive and negative, of the source, each part is called a shunt of the other one and the circuit from the source through either path and back to the source is said to be a shunt circuit. Any circuit in which part of the current may take one path while other parts take other paths consists of or contains shunts. Mutiple and parallel connections are forms of shunt circuits. See also *Winding, Shunt.*

Single-Contact.—A name descriptive of a lamp bulb whose base carries but one metallic point through which current may enter or leave the filament, the other side of the circuit being completed through the shell of the base. Also applied to a lamp base designed to receive such a bulb.

Single-Unit System.—See *One-Unit System.*

Single-Wire System.—See *One-Wire System.*

Solenoid.—A coil of wire without a metallic core, but through which a current may pass and which will produce

magnetic effects and a magnetic field when a current does pass.

Specific Gravity.—A measure of the weight of a liquid which is expressed in decimal fractions or multiples of the weight of an equal volume of pure water. The specific gravity of water is assumed as unity or 1.000. Any liquid one-half as heavy as water will then have a specific gravity of 0.500, while a liquid twice as heavy will have a specific gravity of 2.000 and one, one and one-half times as heavy will have a specific gravity of 1.500. See also Hydrometer.

Speed, Critical.—The speed of a car in miles per hour, of a dynamo armature in revolutions per minute, etc., at which some certain action will take place in some part of the electrical equipment. The speed at which a cut-out will open or close, at which a motor-dynamo will maintain a voltage equal to that of the battery without charge or discharge and at which a speed regulator will act are all critical speeds for those particular actions.

Sponge Lead.—See *Lead, Sponge.*

Start Rate.—In battery charging, the rate of flow or amperage which may be passed through the battery from the beginning until gassing commences to take place in considerable quantity, or the maximum rate that may be safely maintained by the dynamo on the car.

Stop Charge.—Descriptive of any device, such as a relay, that acts to open the field circuit or perform some other action that will result in stopping the flow of current from the dynamo.

Storage Battery.—See *Battery, Storage.*

Sulphate of Lead.—See *Lead, Sulphate of.*

Sulphated.—The condition of a storage battery plate when its surface has become covered with a thick formation of crystals of lead sulphate which prevent normal charge and discharge of the cells affected.

Sulphuric Acid.—The acid used in making storage battery electrolyte. It is composed of two parts of hydrogen, one of sulphur and four of oxygen and is a heavy oily liquid which will rapidly corrode and eat away most materials and will produce severe burns on the flesh. It has a specific gravity of 1.835 for the kind usually employed in battery work. For such use this acid must be chemically pure,

commercial acid not being suitable. Its action on the flesh or clothing may be stopped by the free and immediate application of strong ammonia water.

Switch, Commutating.—A form of switch connected to a battery composed of several sections and which places the sections in series with each other to produce a high voltage for starting while it connects them in multiple for charging and lighting.

Tandem.—A mechanical connection of two electric machines such as a dynamo and motor, a dynamo and magneto, etc., so that one shaft drives them both by passing through one unit and extending to the drive end of the other.

Tapering Charge.—A storage battery charge that decreases in amperage in direct proportion to the rise of voltage of the battery cells. A tapering charge is given by a dynamo whose voltage remains constant because the difference of voltage between dynamo and battery will be great at the beginning of the charge when the battery voltage is low, and will become less and less as the voltage of the battery more nearly approaches that of the dynamo as charging progresses.

Target.—A visible indicator or marker attached to the moving part of a cut-out or to the armature of a magnet whose winding forms part of the charging circuit. The marker will move into view when the cut-out closes or when current flows through the charging circuit.

Three-Unit System.—An electrical installation in which the starting motor, the dynamo and the ignition device are all separate and distinct units with no parts in common.

Three-Wire System.—A form of connection or circuit used for lighting with which two sets of lamps having different voltages may be operated from one battery or by means of which two sets of lamps are attached to two sections of a battery by means of three wires in place of four, the neutral wire acting for either set and being attached to both sections of the battery.

Third Brush.—A brush bearing on the commutator of a dynamo at a point somewhat distant from one of the main brushes and through which current flows to one end of the shunt field winding. The position of the third brush on the commutator determines the amount of current flowing

through the field and the voltage acting at this brush varies in such a way that a rise followed by a fall of voltage and current is obtained with constantly increasing armature speed. Forms a method of regulation.

Torque.—The rotative or twisting power exerted by a shaft.

Touring Switch.—A switch placed in the charging or field circuit or in both of these circuits so that when the switch is opened the charge to the battery will be stopped as may be desirable with a fully charged battery.

Transformer.—A core of soft iron around which are wound two separate coils having different lengths and sizes of wire in each coil. Passage of a current which is pulsating or alternating, or alternate flow and stoppage of a current through one of the coils will produce an induced current in the other. If the exciting or primary current flows through the coil having fewer turns the secondary current from the other coil will be of higher voltage and less amperage, while flow of the primary current through the coil having a larger number of turns will induce a current of lower voltage and greater amperage in the other coil.

Tunnel, Armature.—The cylindrical passage formed between the ends or pole pieces of the field magnets of a dynamo or motor and in which the armature is placed.

Twenty-four Hour Rate.—See *Finish Rate.*

Two-Unit System.—An electric starting, lighting and ignition installation in which two of the units are combined with each other, the third being entirely separate, thus forming two principal parts. Such a system may use a motor-dynamo with separate ignition device, or an ignition-dynamo with separate starting motor.

Two-Wire System.—An electrical installation in which both sides of all circuits are completed through insulated conductors and in which no part of any circuit is carried by the metal of the car.

Under Cut.—To cut away a part of the insulation between commutator segments so that the surface of the segments is above that of the insulation by about $\frac{1}{32}$ inch.

Vacuum Bulb.—An incandescent lamp bulb from which almost all of the air has been exhausted and has not been replaced with any other gas.

Vibrator.—An electromagnet together with its armature and contact points used as a part of a regulator and so designed and connected that the armature and movable contact point vibrate at a high rate of speed so that the circuit completed through the contacts is rapidly opened and closed.

Volt.—The unit of electrical pressure, potential or electromotive force. One volt pressure is produced in a conductor that cuts or is passed through by one hundred million lines of magnetic force per second. One volt pressure will cause a flow of one ampere through a circuit whose resistance is one ohm.

Voltage.—The electrical pressure existing between two points.

Voltage, Constant.—Descriptive of a form of regulation that allows the dynamo voltage at the dynamo terminals to rise to a predetermined maximum and then causes this voltage to be maintained without any great rise or fall at all higher speeds of the dynamo.

Voltammeter.—A single measuring instrument that may be used either as an ammeter or a voltmeter. Also an instrument consisting of a voltmeter and a separate ammeter in one case.

Voltmeter.—An instrument that measures difference in electrical pressure between two points and which indicates this difference directly in volts on a suitable scale.

Watt.—The unit of electrical power. The power delivered by a circuit through which one ampere flows at a pressure of one volt. The number of watts may be found by multiplying the number of volts by the number of amperes of a circuit. One watt is equal to 1/746th of a mechanical horsepower. One watt is the power that must be developed to do 44¼ foot-pounds of work per minute.

Watt-Hour.—A unit of electrical work equal to a power of one watt used or applied for one hour.

Winding.—A coil composed of one or a number of turns of a conductor around a magnetic core.

Winding, Compound.—A form of dynamo or motor field winding consisting of a shunt and a series winding wound on the same or separate magnet cores and acting on one armature.

Winding, Series.—In a dynamo or motor, a field winding through which passes all of the current that flows through the armature and brushes and in which the armature windings and field windings are in a series circuit with each other. In a cut-out, controller or regulator magnet, the winding or part of the winding through which all of the charging current passes.

Winding, Shunt.—In a dynamo or motor-dynamo, a field winding placed in shunt with the armature windings and with the outside circuits and through which only a part of the current that is generated in the armature or that is received from an outside source will flow. The shunt field winding is made of much higher resistance than the outside circuits so that no more than the necessary amount of current required to magnetize the field magnets will pass through the winding. In a cut-out, controller or regulator magnet, the winding that is connected to the positive side of the dynamo at one end and to the negative terminal of the dynamo at its other end which is always acted upon by the difference in pressure or voltage between the dynamo brushes.

Zero Center.—Descriptive of an electrical measuring instrument such as a voltmeter or ammeter in which the indicating pointer may travel from the zero point toward either end of the scale, both sides being graduated and having the zero point at the center of the scale or nearer to one side than to the other so that a reading of greater value may be obtained with current flowing in one direction than with it flowing in the other. The latter class of instruments is not properly named "zero center" but should be designated by the maximum readings each way, thus "10-0-30" meaning an instrument that will read to ten amperes or volts one way and to thirty amperes or volts in the other direction.

EXAMINATION QUESTIONS

Part I, Chapters I and II

1. What are the two forms of electricity in motion?

2. Is an electric charge standing still or in motion?

3. What are the units for measuring (a) volume of current flow, (b) electrical pressure, and (c) resistance to current flow?

4. What are the units for measuring (a) electric power and (b) quantity of electricity in automotive work?

5. What are two other names for electrical pressure?

6. What is the total load in a circuit including two lamps each having 2 ohms resistance, and 20 feet of wire having a resistance of 1/10th ohm per foot,

7. Using the symbols *I* for amperes, *E* for volts, and *R* for ohms, write the three forms of Ohm's law expressed in equations.

8. How many amperes will flow in a circuit having 3 ohms resistance if the pressure is 15 volts?

9. In a circuit containing an ignition coil having 2 1/2 ohms resistance and other parts and

conductors with 1 1/2 ohms resistance, how many amperes will flow from a battery having 12 volts pressure?

10. How many volts will be required to send 2 1/2 amperes through a circuit having 3 ohms resistance?

11. What is the resistance of a circuit in ohms when 6 volts pressure causes a current flow of 2 amperes?

12. How many ohms resistance must be used in a circuit to allow a current of only 1 ampere with a pressure of 8 volts from a generator in the circuit?

13. Inside of a source of current which way does the current flow, from positive to negative terminal, or from negative to positive?

14. Does resistance become greater or less (a) with increase of conductor length, (b) with increase of conductor area?

15. What kind of a circuit is it in which all of the current through any one part flows also through every other part?

16. What is the total resistance of a series circuit containing one lamp of 2 ohms resistance, a dimmer coil with 1 ohm resistance and conductors having 1/2 ohm resistance?

17. What will be the voltage drop or potential difference in a part of a circuit having 7 ohms resistance and carrying 2 amperes?

18. What is the combined resistance of three shunts, each with a resistance of 6 ohms?

19. What is the combined resistance of two side lamp circuits, one tail lamp circuit, and one dash lamp circuit, each having a resistance of 4 ohms and all being shunts of a main circuit?

20. A head lamp circuit having 3 ohms resistance and a side lamp circuit with 6 ohms resistance are in parallel. What is the total resistance of the shunt circuit thus formed?

21. Three circuits are in shunt with each other. One has 2 ohms resistance, another has 10 ohms resistance, and the third has 15 ohms resistance. What is their combined resistance?

22. Three circuits are in parallel on a battery. The ignition circuit has 4 ohms resistance, the carburetor heater has 2 ohms resistance, and the spot lamp circuit has 3 ohms resistance. What is the combined resistance of the three circuits together when in shunt?

23. What other name is sometimes given a multiple connection?

24. Does the direction of flow reverse in a pulsating current?

25. What are the two principal parts which work together to form an electromagnet?

26. A certain electromagnet has 46 full turns of conductor around the core and a current of 2 1/2 amperes flows through the winding. What is the strength of this electromagnet measured in ampere-turns?

27. Which electromagnet has the greater strength in ampere turns; one carrying 12 amperes through 6 turns, or one carrying 5 amperes through 15 turns?

28. What is the action called by which an electromotive force is produced in one conductor by a change of current strength in another conductor?

29. Does self-induction tend to help the change of current strength in a conductor, or does it oppose any rise or fall of current?

30. What is the action called by means of which an electromotive force in produced in a conductor when it cuts through magnetic lines of force?

Part II, Chapter I

31. Name the principal parts of the charging system?

32. Name the principal parts of the starting system?

33. Name the principal parts of the lighting system?

34. In which of these systems is the battery included?

35. What are the two principal parts of a generator armature?

36. What is the purpose of the commutator as used on a generator?

37. At what part is connection made between the different coils of the armature?

38. Are the two circuits through an armature from brush to brush in parallel or series with each other?

39. What is a distinguishing feature of a lap winding?

40. What is a distinguishing feature of a wave winding?

41. What two magnetic fields act on each other to cause the effect of armature reaction?

42. Are the field lines of force carried around with the direction of armature rotation or against rotation by the armature reaction?

43. Should there be a high or low pressure or voltage between commutator bars on which the brush end rests?

44. What are the two things which make it necessary to move the generator brushes to prevent sparking?

45. Are the generator brushes moved in a direction with armature rotation or against rotation to prevent sparking?

Part II, Chapter II

46. Are field windings placed on consequent poles?

47. What are the other two circuits with which a generator shunt field winding is in parallel?

48. Is a shunt field winding used principally in generators or in starting motors?

49. With what two circuits is a series field winding in series connection?

50. What two windings are included in a compound field winding?

51. In a reversed series field winding, does the series field assist or oppose the shunt winding?

52. For what purpose is a reversed series field winding used in generators?

53. What connections must be changed to reverse the direction of rotation of a generator?

54. What kind of field winding will be found in all starting motors?

55. Explain briefly the reason for the rotation of an armature in a starting motor?

56. What connections must be changed to reverse the direction of rotation of a starting motor?

57. Will reversal of the direction of battery current through a series wound motor reverse the motor's direction of rotation?

58. How many cores are used in the armature of a motor-generator?

59. What two kinds of field windings are found in motor-generators?

60. What function may the series winding perform in a motor-generator while the unit is acting as a generator?

Part II, Chapter III

61. With a shunt wound generator, does the current output tend to increase or decrease as the battery nears a state of full charge?

62. Is the field current or the armature current regulated to limit the output of generators?

63. What is the cause of the field distortion utilized in third brush regulation?

64. Between what points is the shunt field connected in third brush generators?

65. Does the output of a third brush generator increase or decrease at the highest speeds?

66. What change is made to increase the maximum output of a third brush generator?

67. Which way is the third brush moved to decrease the maximum output of a third brush generator?

68. What is the effect of a reversed series field winding on generator output at high speeds?

69. What current passes around the magnet in a regulator for constant amperage control?

70. When is the regulating resistance working in series with the field circuit during the operation of a constant amperage regulator?

71. Between what points is the regulator magnet winding connected with a vibrating type of constant voltage regulator?

72. Is it the voltage or the amperage of the generator that affects the magnet strength in a vibrating type of constant voltage regulator?

73. What are the two principal parts of the thermostat as used for generator output control?

74. Is the output increased or decreased with a hot generator by the thermostat control?

75. What is the name of a device which controls one circuit by the effect of another circuit on the device?

Part II, Chapter IV

76. Under what condition of generator operation should the cut-out remain open?

77. What is the purpose of the cut-out?

78. Are the cut-out contacts closed by the action of the shunt coil or of the series coil?

79. Through which winding of the cut-out does the battery charging current flow?

80. Which winding of the cut-out acts to demagnetize the magnet as the generator comes to a stop?

81. What is the relation between battery voltage and generator voltage at the instant the cut-out should close?

82. Which direction should current be flowing between battery and generator when the cut-out opens?

83. To make a cut-out close at lower generator voltage, (a) should the spring tension be increased or decreased, (b) should the armature gap be increased or decreased?

84. Will an increase of spring tension make the cut-out close earlier or later?

85. Will an increase of armature gap make the cut-out close earlier or later?

86. What is done with the spring tension to make the cut-out open quicker?

87. What is done with the spring tension to make the cut-out open with a greater discharge?

88. Is it best to alter the spring tension or the armature gap to adjust the cut-out opening?

89. Is it best to change the spring tension or the armature gap to adjust the cut-out closing?

90. During what condition of generator operation will there be a discharge from the battery after a manual cut-out is closed?

Part II, Chapter V

91. What other metal is alloyed with lead to make the plate grids?

92. Of what is the active material composed in charged positive plates; of what in negative plates?

93. Of what is the electrolyte composed?

94. What is the color of a fully charged positive plate; of a fully charged negative plate?

95. Of what polarity are the two outside plates in every cell in automotive batteries?

96. What is the cell voltage at the beginning of a charge, starting from a discharged condition; what is the voltage at the end of a charge?

97. What is the cell voltage when the cell has been completely discharged to its working limit?

98. What substance is formed on both kinds of plates as the battery is discharged?

99. During discharge, does the electrolyte become weaker or stronger in acid?

100. Can a greater discharge in ampere-hours

be secured with low rates or with high rates of discharge?

101. What are the two kinds of current that may be used for battery charging?

102. Between what specific gravity readings may the battery be considered fully charged?

103. At what specific gravity reading is the battery completely discharged to its working limit?

104. How high above the plate tops should the level of electrolyte be maintained?

105. With a floating battery, will the battery be charged or discharged when the lamp load is greater than the generator's output?

Part II, Chapter VI

106. Which has the greater area of conductor; a cable composed of ten strands of number 24 wire or a single wire of number 14 gauge? (Refer to page 199.)

107. If the maximum current to be carried is 25 amperes, what is the smallest gauge wire that should be used? (Refer to page 199.)

108. What will be the weight in pounds of 20 feet of number 00 starting cable? (Refer to page 199.)

109. How many feet of number 22 wire will be in one pound? (Refer to page 199.)

110. What is the total area in circular mils of ten strands of number 20 gauge wire? (Refer to page 199.)

111. What will be the gauge size of a single conductor wire which is the approximate equivalent in area of the ten strands of number 20 gauge? (Refer to page 199.)

112. Which will have the greater resistance in ohms, 100 feet of number 16 wire or 150 feet of number 14 wire, taking the resistances of cool wires? (Refer to page 199.)

113. What is the resistance in ohms of a field coil containing 30 feet of number 18 gauge wire after the generator gets hot? (Refer to page 199.)

114. How many amperes of current will flow to two 20 candlepower headlamps and one 2 candlepower tail lamp on a six-volt system? (Refer to page 190.)

115. A car using six-volt equipment is equipped with two 21 candlepower headlamps, two 8 candlepower side lamps, a 2 candlepower dash lamp, and a 4 candlepower tail lamp. With all lamps turned on, how many amperes should they draw? (Refer to page 190.)

116. On a six-volt system, what size fuses should be used for tail and dash lamps? (Refer to page 209.)

117. With two lamps in series on a six-volt battery, what should be the bulb voltage for each?

118. Does wire size increase or decrease as the gauge numbers get larger?

119. Is it best to connect one side of a voltmeter between the generator brushes and the cut-out, or between the cut-out and the battery line?

120. Is the resistance method of dimming economical of current consumption?

Part II, Chapter VII

121. Will a greater amperage flow through the starting motor when pulling hard at low speed or when running fast?

122. How many pounds must be lifted one foot high in one minute to equal one horsepower of work?

123. Is the horsepower of a starting motor greatest at low, medium, or maximum speeds?

124. What part of some Delco starting motors takes the place of a starting switch?

125. What electrical principle is utilized in magnetic starting switches and magnetic gear shifts?

126. With what type of electric machine is the starting switch allowed to remain closed after the engine starts?

127. With an electrical system cranking at one voltage and charging the battery at a lower voltage, what type of starting switch is used?

128. Is the power of the starting motor carried by the spring of the Bendix drive?

129. At what time does the pinion of the Bendix drive pass out of mesh with the flywheel gear?

130. What parts carry the drive between the two rings or races of an overrunning clutch?

131. Does the same current pass through the magnet of a magnetic pinion shift that passes through the starting motor?

132. Between what two parts of a Rushmore motor does the magnetic attraction act to mesh the starter gears?

133. With a spring operated starting switch, is it possible for the switch to close before the gears have fully meshed?

134. What is the approximate torque in foot-pounds required to start a four-cylinder engine having a 3 1/2 inch bore and 4 inch stroke? (Refer to page 238.)

135. What is the torque in foot pounds required to keep the 3 1/2 by 4 inch 4-cylinder motor turning after being started from rest? (Refer to page 238.)

Part II, Chapter IX

136. Will current be flowing in any part of a circuit containing an open point?

137. Will current be found to flow through all the parts of a circuit containing a short or ground?

138. With a voltmeter bridging around a part containing an open circuit, will the meter show high or low voltage?

139. With a lamp circuit tester in a circuit containing an open, will the lamp light or remain out?

140. With a voltmeter in series with a circuit being tested for shorts and grounds, and with successive connections in the circuit being opened one after the other, where is the fault located when the meter shows a drop of voltage or shows zero voltage?

141. In testing for a ground with a lamp circuit

tester connected between the metal of the car and the suspected conductor, will the lamp light or remain out if there is an accidental ground?

142. With two current carrying conductors immersed in water containing acid or salt, which will give off the greater amount of bubbles, the positive or the negative conductor?

143. Name five causes for failure of lamps to light.

144. Name three brush troubles.

145. Name three commutator troubles.

146. Name two common armature troubles.

147. Name three kinds of field trouble.

148. Are brush troubles found with a third brush or regulating brush any different than those found with any other brushes?

149. Name three troubles which may affect a vibrating type of regulator.

150. Name five troubles which may affect an electromagnetic cut-out.

Part III, Chapter I

151. Is any other type except jump spark ignition used on modern automobiles?

152. Name the four strokes of a four-cycle engine in the order in which they occur, starting with the intake stroke.

153. Between what two strokes does the firing point come?

154. At or near which "center," top or bottom, does the firing point come?

155. What is the principal reason which makes spark advance necessary?

156. What is meant by a variable spark ignition system?

157. What is meant by a set spark ignition system?

158. In ignition work, what is another name for low tension and what is another name for high tension?

159. How many kinds of windings has the usual type of ignition coil?

160. Is the high voltage current in a coil caused by an increase or decrease of primary current?

161. Which will produce the highest voltage from an ignition coil, a quick change or a slow change of current strength in the primary winding?

162. Name the principal sources of ignition current on automobiles.

163. What will be the total voltage of five dry cells connected in series?

164. What will be the total voltage of five dry cells connected in multiple.

165. How many sources of current may be used with a dual ignition system?

Part III, Chapter II

166. Name the principal parts of the breaker.

167. Does the spark take place as the contacts come together or as they separate?

168. Is the primary circuit always grounded on one side?

169. Of what two metals are contact points generally made?

170. Which contact is generally adjustable to alter the gap, the one moved by the cam or the stationary one?

171. With a four-cycle engine, how many sparks are required for each crankshaft revolution if there are eight cylinders?

172. With relation to the speed of the engine crankshaft, how fast does the breaker shaft turn for battery ignition systems?

173. With a breaker whose contacts are held closed by the spring (closed circuit type) does the spark take place when the cam strikes the bumper or when it leaves the bumper?

174. With a breaker whose contacts are held apart by the spring (open circuit type) does the spark take place when the cam strikes the bumper or when it leaves the bumper?

175. Will direct current pass through a condenser in good condition?

176. What effect does the condenser have on the electrical action of the breaker contacts?

177. How does the action of the condenser assist the coil to produce a hotter spark?

178. In what two locations will the condenser usually be found?

179. About how great should be the gap in a jump spark type of distributor?

180. Is there any gap in the normal secondary circuit through a wipe contact distributor?

Part III, Chapter III

181. In a closed circuit ignition system are the breaker contacts held together or held apart by the spring?

182. Which is more generally used, closed circuit or open circuit ignition?

183. Of what kind of wire is the resistance unit usually made?

184. Under what conditions will the resistance unit cut down the flow of current through the coil?

185. Should the resistance of a safety spark gap be greater or less than the resistance of a spark plug gap?

186. Which one of the two windings in an ignition coil is made of comparatively heavy wire?

187. Approximately how many turns of wire are used in the secondary winding of an ordinary ignition coil?

188. Name three commonly used materials for spark plug insulators.

189. With spark plug gaps in parallel, as usually arranged, is it possible to cause more than one spark at a time?

190. What is the normal setting for a spark plug gap with battery ignition systems?

191. With missing at low speeds on a battery ignition system, should the spark plug gap be increased or decreased?

192. With magneto ignition, does low speed missing call for a larger or a smaller gap at the spark plug?

193. What is the diameter and how many threads to the inch are used in the S. A. E. standard spark plug?

194. What is the name of the spark plug having a tapered thread?

195. Is primary ignition cable used to carry the high voltage or the low voltage current?

Part III, Chapter IV

196. For breaker timing with battery systems, is the spark control placed in its retarded or advanced position?

197. By watching the action of the valves, how may the top center between compression and firing strokes be located approximately?

198. When moving the breaker cam for ignition timing, should the cam be turned in the direction it runs or in the opposite direction?

199. With the control retarded, at what position of the piston should the breaker contacts separate?

200. Name the two firing orders for four-cylinder engines.

201. Name the two firing orders for six-cylinder engines.

202. How may the firing order of an engine be determined if it is not marked on the engine?

203. At which end of the engine is number 1 cylinder?

204. When wiring the distributor, with number 1 piston at its firing point, how is the distributor terminal for number 1 cylinder located?

205. After connecting the wire from the distributor to number 1 cylinder, which distributor terminal is connected to the spark plug in the next cylinder to fire?

206. With the spark control fully advanced, should the distributor rotor make connection at the end of the segment first approached during rotation, or at the opposite end?

207. With the ignition control lever midway between advance and retard, at approximately what part of the segment should contact be made by the distributor rotor?

208. Is greater spark advance required for slow speed or for high speed of the engine?

209. In which direction is a breaker housing carrying the contacts moved to retard the spark?

210. In which direction is a breaker cam turned to secure greater advance of spark timing?

Part III, Chapter VI

211. Does the Ford magneto generate direct or alternating current?

212. In mounting the Ford magneto magnets, should adjacent poles be of the same or opposite polarity?

213. Where is the condenser mounted in the Ford ignition system?

214. How should the Ford coil vibrator screw be turned to make an adjustment?

215. In timing the Ford commutator, where should the ignition control lever be placed?

216. Where should number 1 piston be placed while timing the commutator?

217. With which segment of the commutator should the roller be starting to make contact while timing the Ford ignition system?

218. What is the firing order of the Ford engine?

219. Name three troubles which may affect the vibrator or the contacts of the Ford coil.

220. What trouble may be found with the magneto terminal on top of the flywheel case?

221. If the voltage from the Ford magneto is between 11 and 12 at 20 miles an hour, is the magneto in satisfactory condition?

222. Name three troubles which may affect the fibre ring or the segments in the Ford commutator.

223. Name three troubles that may be found with the commutator roller and spring.

224. Should light or heavy grease be used in the Ford commutator housing?

225. Is there any difference in the principles governing the coil and condenser of the Ford system from those governing similar parts used with other ignition systems?

Part III, Chapter VII

226. At what time during rotation of a magneto armature is the greatest voltage produced in the primary winding?

227. Do the coils revolve in an inductor magneto?

228. What parts of a transformer coil magneto are used with both sources of current?

229. Where is the secondary winding carried in a true high tension magneto?

230. What parts of a dual magneto are used with both sources of current?

231. How many breakers may be carried on a dual magneto?

232. Does a starter coil with a vibrator produce sparks at the plugs while the magneto breaker contacts are together or separated?

233. With two-spark ignition, are the two plugs in one cylinder connected in series or in parallel with each other?

234. In a magneto breaker, what are the two locations which may be used for the cams?

235. With a magneto breaker just opening and with the control set at full advance, should the dis-

tributor rotor be starting to make contact with a segment or should it be leaving a segment?

236. Is here any essential difference between timing a magneto breaker and a battery breaker?

237. When bringing the magneto breaker contacts to the point of separation, should the magneto drive shaft be turned in the direction it runs or in the opposite direction?

238. When timing a magneto with the control in the advanced position, should the control arm on the breaker be moved with rotation or against rotation?

239. In timing a magneto with the control advanced, what should be the gap between the edge of the pole piece and the edge of the armature core?

240. At what time during the engine cycle should the spring of an impulse starter coupling release?

Part III, Chapter IX

241. With the spark control retarded and a piston at top center following compression, how should the breaker contacts act when the cam is rocked back and forth?

242. What should be done to make breaker contacts meet squarely?

243. How should the breaker arm fit on a pivot bearing, freely or tightly?

244. What kind of trouble is indicated by excessive flashing at the breaker contacts?

245. How far should the spark from a coil jump in the open air?

246. Should the tension of distributor brush springs be light or heavy?

247. What should be the measurement of the safety spark gap?

248. What is the correct spark plug gap for battery ignition systems?

249. What is the correct spark plug gap for magneto ignition?

250. With the ignition switch closed and the breaker contacts together, how should the ignition resistance act?

251. What is the usual cause of excessive play in magneto armature shafts?

252. Mention three places at which brushes may be found in a magneto.

253. Of what polarity should be all the magnet ends on one side of a magneto?

254. What will be the effect of poor compression on the operation of an engine?

255. While short circuiting a spark plug, what is indicated if the shorting makes no noticeable difference in the running of the engine?

ANSWERS AND REFERENCES FOR EXAMINATION QUESTIONS

The answers for the questions and problems which do not require making any numerical calculations will be found in the Reviews following each of the Chapters to which the questions apply. In making corrections of the answers, reference should be made to these Reviews.

The answers for questions requiring calculations are given on the following pages in numerical order.

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1 to 5. See Review on page 42.
6. Total load, 6 ohms (use Ohm's law).
7. See Review on page 42.
8. The flow will be 5 amperes (use Ohm's law).
9. The flow will be 3 amperes (use Ohm's law).
10. The voltage will be 7 1/2 (use Ohm's law).
11. The resistance is 3 ohms (use Ohm's law).
12. The resistance must be 8 ohms (use Ohm's law).

13 to 15. See Review on page 42.
16. Total resistance is 3 1/2 ohms (see page 43).
17. The drop will be 14 volts (see page 43).
18. The total resistance is 2 ohms (see page 43).
19. The total resistance in 1 ohm (see page 43).
20. The total resistance is 2 ohms (see page 43).
21. The total resistance is 1 1/2 ohms (see bottom of page 43).

22. The total resistance is 12/13 of an ohm (see bottom of page 43).

23 to 25. See Review on page 43.

26. The strength will be 115 ampere-turns (see page 44).

27. The 12 amperes through 6 turns give 72 ampere-turns, and the 5 amperes through 15 turns give 75 ampere-turns (see page 44).

28 to 30. See Review on page 44.

31 to 45. See Review on page 65.

46 to 60. See Review on page 81.

61 to 75. See Review on page 136.

76 to 90. See Review on page 160.

91 to 105. See Review on page 187.

106. Ten strands of No. 24 have a total area of 4,040 circ. mils, while one No. 14 wire has an area of 4,107 circ. mils (see page 199).

107. Number 14 gauge should be used (see page 199).

108. Number 00 has 2.48 ft. per lb., and 20 divided by 2.48 gives 8.06 lbs (see page 199).

109. Number 22 has 514.2 ft. per lb (see page 199).

110. One Number 20 wire has an area of 1,022 circ. mils; ten strands have 10,220 circ. mils (see page 199).

111. Number 10 wire has an area of 10,380 circ. mils (see page 199).

112. One hundred feet of Number 16 wire has a resistance of .401 ohm; while 150 feet of Number 14 wire has a resistance of .3781 ohm (see page 199).

113. The resistance of 30 ft. of Number 18 wire, hot, is .2367 ohm (see page 199).

114. Two headlamps will take 38 watts and one tail lamp will take 2.4 watts, a total of 40.4 watts which, with 6 volts pressure, takes 6.73 amperes (see table on page 190).

115. Headlamps take 39.9 watts; side lamps take 16.0 watts; dash lamp takes 2.4 and tail lamp takes 4.8 watts; a total of 63.1 watts, which, at 6 volt pressure, requires about 10.5 amperes (see page 190).

116. For tail and dash lamps use 5-ampere fuses (see page 209).

117 to 120. See Review on page 219.

121 to 133. See Review on page 254.

134. The starting torque will be 73 foot-pounds (see page 238).

135. The running torque will be 17 foot-pounds (see page 238).

136 to 150. See Review on page 304.

151 to 162. See Review on page 397.

163. Five dry cells in series give 7 1/2 volts (see page 397).

164. Five dry cells in multiple will give 1 1/2 volts, the same as one cell (see page 397).

165. See Review on page 397.

166 to 170. See Review on page 425.

171. Four sparks for each crankshaft revolution (see page 425).

172 to 180. See Review on page 425.

181 to 195. See Review on page 462.

196 to 210. See Review on page 500.

211 to 225. See Review on page 578.

226 to 240. See Review on page 631.

241 to 255. See Review on page 734.

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